California High-Speed Train Project

TECHNICAL MEMORANDUM

High-Speed Equipment Structure Gauges
TM 1.1.10

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Revision	Date	Description
0	19 Mar 10	Initial Release, R0

Prepared by PB

for the California High-Speed Rail Authority

System Level Technical and Integration Reviews

The purpose of the review is to ensure:
- Technical consistency and appropriateness
- Check for integration issues and conflicts

System level reviews are required for all technical memoranda. Technical Leads for each subsystem are responsible for completing the reviews in a timely manner and identifying appropriate senior staff to perform the review. Exemption to the System Level technical and integration review by any Subsystem must be approved by the Engineering Manager.

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Infrastructure	*Signed document on file* John Chirco	8 Oct 09 Date
Operations:	*Signed document on file* Paul Mosier	7 Mar 10 Date
Maintenance:	*Signed document on file* Paul Mosier	7 Mar 10 Date
Rolling Stock:	*Signed document on file* Frank Banko	12 Oct 09 Date

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ABSTRACT

This technical memorandum presents guidance for the clearance requirements to be used in the basic design in order to meet applicable regulatory requirements, to achieve a safe and reliable operating railroad, for the operational and performance requirements for all the equipment types that potentially may operate on the California High-Speed Train (CHST) rail lines.

Specifically, this technical memorandum presents the Design Criteria for determination of required clearances around tracks and vehicles. The clearance requirements addressed will be clearance requirements necessary to pass the known currently available high speed rail vehicles from Europe and Asia. It does not include any consideration for other passenger equipment, freight equipment, or other equipment larger than the largest high speed rail passenger vehicle.

This memorandum presents the gauge and clearance diagrams for use on CHSTP including:

- Gauges illustrating the equipment static gauges and equipment outlines for high-speed equipment traveling on CHST rail lines
- Dynamic outlines developed by the manufacturer of the vehicle to track-related factors that are independent of speed
- Structural gauges with their application.

Clearance requirements for pantographs and overhead electrical equipment will be in another technical memorandum.

1.0 INTRODUCTION

This technical memorandum presents the basis of design for determination of desirable, minimum, and exceptional Structural Gauges around tracks and vehicles necessary to pass the known currently available high speed rail vehicles from Europe and Japan. This document does not include:

- Consideration for any equipment larger than the largest high speed rail passenger vehicle.
- Clearance requirements for pantographs and overhead electrical equipment.

The Structure Gauges developed in this technical memorandum will be used to develop minimum and typical cross sections for tunnels, through bridges, and other types or roadway.

Following review, specific guidance in this technical memorandum will be excerpted for inclusion in the CHSTP Design Manual.

1.1 PURPOSE OF TECHNICAL MEMORANDUM

This technical memorandum will develop and present the following:

- Static Gauges: Outlines that will define the maximum size of equipment that will be operated on the tracks of the CHSTP that will carry high speed equipment, only.
- Dynamic Outlines: Outlines defining the maximum likely swept path of the equipment that will be operated on the CHSTP tracks that will carry high speed equipment, only.
- Structure Gauges: Outlines defining the minimum acceptable approach of various structures to the CHSTP tracks.

Variations in these outlines due to the effects of curvature, superelevation, and speed will also be discussed. Clearances for the Overhead Contact System (OCS) and pantographs will be addressed in another technical memo.

1.2 STATEMENT OF TECHNICAL ISSUE

Types of equipment to be considered will only be high-speed passenger trains – clearances so as to permit all types under consideration.

High-speed train equipment will presumably be of either Asian or European design and manufacture. This equipment has a very tight suspension supporting a car body that will have a limited range of motion in any direction providing for good performance at high speeds on track built and maintained to a high quality for high speed operation.

1.3 CONCEPTS AND DEFINITIONS

1.3.1 Static Gauge

The Static Gauge defines the maximum dimensions to which a particular piece of railroad equipment may be fabricated. It includes tolerances in the manufacture of the vehicle itself, but no allowances for any motion of the car on the railroad or allowances for uneven wear of components. It is common that the static gauge will be a few millimeters greater in dimensions than the actual vehicle. It is also common that the actual vehicle will not precisely follow the outlines of the static gauge, particularly in the upper and lower corner areas. There are two primary and one secondary sources for static gauge information:

- **Japan:** a specific static gauge for the Shinkansen vehicles.
- **Europe:** a series of Static Gauges developed under the umbrella of the Union International de Chemin des Fer (UIC), (in English the International Union of Railways) have historically been used by many Western European countries. More current is the European Union's Technical Specifications for Interoperability (TSI), which is a set of standards required of all railroad systems in the European Union. For high speed railroad systems, they were first published as Council Directive 96/48/EC—Interoperability of the Trans-European High Speed Rail System. In the countries that are part of the European Union these standards have the force of law. The clearance diagrams are in the document for freight rolling stock which is referenced by the

passenger rolling stock TSI. There are four Vehicle Gauges, G1, GA, GB, and GC, in order from smallest to largest. Most European equipment is built to fit within either the GA or GB outline. The Infrastructure TSI requires all new lines be built to clear the GC outline.

- **North America,** meaning the connected standard gauge system of the United States, Canada, and Mexico: Association of American Railroads (AAR) Equipment Diagrams for Interchange Service. Certain points of information from this source are useful in the development of the Static Gauge.

The Static Gauge selected to determine the Dynamic Outline and Structure Gauge will be that which will encapsulate both the Japanese bi-level Shinkansen and the EU GC Gauge.

1.3.2 Dynamic Outline

The Dynamic Outline is the limit of the vertical, lateral and rotational movement of a vehicle under a defined set of forces and conditions. Normally the outline of concern is that which takes the vehicle to the physical limits of motion under the maximum conceivable forces combined with the maximum allowable limits of wear and deficiencies. In addition, certain defects such as deflated airbags in passenger car suspension or broken springs may be included in the calculation. It is not always the largest piece of equipment that makes the largest dynamic outline.

For purposes of determining minimum worst case structural offsets, dynamic outlines must include effects of track deficiencies, and such deficiencies will be included in the analysis in this document.

1.3.3 Structure Gauge

The Structure Gauge defines the physical relationship and dimensions between various structures and adjacent tracks. It is typically represented in a composite outline incorporating multiple structure types. Structure Gauges are based on the dynamic outline plus a clearance allowance. In addition, the Structure Gauge will include working space around the tracks, evacuation walkways, space to install fixtures inside the structures, plus some allowance for additional items not necessarily anticipated in the original design. In many railroads and transit systems the initially determined Structure Gauges were found to be too small to easily provide space for convenient installation of all equipment and space for ease of maintenance and operation either initially or later.

The general basis for Structure Gauge requirements, in addition to the standards given in this document, is American best practices as described in the Manual for Railway Engineering of the American Railway Engineering and Maintenance-of-Way Association (AREMA) Manual, Chapter 28, Clearances.

High speed operation will require consideration of aerodynamic effects. These effects will result in larger tunnel cross sections and greater spacing to objects than simply that required for passing the equipment. Aerodynamic related clearance requirements will be defined in another Technical Memo.

Passenger platforms are required to be located so as to minimize both the horizontal and vertical gap between platform and car floor at doorway to provide for safe and efficient passenger loading and unloading. Barrier free access requirements also affect the positioning of the track side passenger platform edge. Passenger platform edges will therefore fall inside the Dynamic Outline. Platform edge location relative to the track is a special case dependent upon the width and floor elevation of the equipment selected. Platform edge locations and other platform related issues will be covered in other Technical Memos.

1.3.4 Definition of Terms

The following technical terms and acronyms used in this document have specific connotations with regard to California High-Speed Train system.

Dedicated Corridor	Segment along the CHSTP alignment where high-speed trains operate exclusive of other railroads' equipment.
Dedicated Track	A track on which only high speed trains may operate. It may or may not be in a Dedicated Corridor.
Design Standard Classifications	The design standards presented in this document will normally be described using three terms:

Desirable	The standard which shall be equaled or exceeded where there are no constraints.
Minimum/Maximum	The standards which shall be equaled or exceeded where constraints make use of Desirable standards impractical or significantly more expensive than if Minimum/Maximum standards are used. Where Desirable standards are not obtainable, they shall be approached as nearly as practical.
Exceptional	The absolute limit standard which shall be achieved. This standard shall be used only where Minimum/Maximum standards are either unobtainable or exorbitantly expensive. Where Minimum/Maximum standards are not obtainable, they shall be approached as nearly as practical. A waiver is required to go beyond Minimum/Maximum limits.
Dynamic Outline	Also called Kinematic Envelope. It is the trace of the maximum limits of movement of the vehicle in normal service. This outline is defined by the limits of motion due to wear of various components to their limits and includes deficiencies such as deflated / overinflated airbags, etc. When defined from the perspective of the vehicle in normally does not include any track position considerations. For purposes of this Technical Memo, allowances for track deviations are included.
Equilibrium Superelevation:	The calculated superelevation that exactly balances the lateral force of the train on the curve at the defined speed. Normally called Balancing Cant or Equilibrium Cant in European publications
Speed, Design:	The maximum speed permissible on a section of alignment based on the speed permitted by the various design elements.
Speed, Operating:	The maximum speed normally achieved by a train on a section of alignment when train speed is not reduced by some abnormality.
Spiral	A curve of variable radius used to connect a straight section of track with the radius of the body of the curve. Sometimes call a Transition or a Transition Spiral in European publications.
Static Gauge	The maximum outline to which a vehicle may be fabricated. It will include only manufacturing tolerances. There are several standard outlines that have been developed by various systems and international associations. Those of interest here are the Shinkansen Outline, the European Union G-series Gauges and the Association of American Railroads Plates B through H.
Station Track / Platform Track	A track for the purpose of bringing a train alongside a station platform for a stop to embark / disembark passengers.
Structure Gauge	The Outline defining the minimum distance from track centerline to various features. The Structure Gauges developed in this Technical Memo includes neither space for the Overhead Contact System nor any allowance for aerodynamic effects or other issues that may require greater offsets and cross sectional area than those defined in this Technical Memo.
Superelevation	The difference in elevation between the outside rail of a curve and the inside rail of a curve measured between the highest point on each rail head. (“Cant” in European publications.). Usual symbol: Ea.
Track Centerline	The line equidistant between the inside faces of the rail heads.
Track Centers	Distance between track centerlines of adjacent tracks

Top of Rail	The top of the rail on the track. The top of the rail defines the profile elevations of the track. On curves with superelevation it is the top of the inside rail, also commonly called the top of low rail.

Acronyms

AAR	Association of American Railroads
AREMA	American Railway Engineering and Maintenance of Way Association
CHSTP	California High-Speed Train Project
Caltrans	California Department of Transportation
CFR	Code of Federal Regulations
CPUC	Public Utilities Commission of the State of California
DB	Deutsche Bahn (German Railway)
FRA	Federal Railroad Administration
GO	General Order
SNCF	Société Nationale des Chemins de fer Français (French National Railway)
TSI	The European Union's Technical Specifications for Interoperability
UIC	Union International des Chemins de Fer (International Union of Railways – The French acronym is also used in English.)

1.3.5 Units

The California High-Speed Train Project shall be designed and constructed in U.S. Customary Units consistent with guidelines prepared by the California Department of Transportation and defined by the National Institute of Standards and Technology (NIST). U.S. Customary Units are officially used in the United States, and are also known in the US as "English" or "Imperial" units. In order to avoid any confusion, all formal references to units of measure should be made in terms of U.S. Customary Units.

2.0 DESIGN STANDARDS AND GUIDELINES

2.1 BASIS

Available high speed railroad equipment is manufactured in Asia and Europe and is built to standards prevailing there. The clearance requirements for these vehicles will be analyzed and clearance standards for the CHSTP selected so as not to preclude the use of suitable available high speed equipment. The Japan Railway Technical Service has provided Shinkansen clearance diagrams. Information on European requirements has been extracted from the TSI and various French and German sources of information.

The general basis for design standards will be the most applicable of the "recommended practice" described in the Manual for Railway Engineering of the American Railway Engineering and Maintenance-of-Way Association (AREMA Manual). Certain International Union of Railways documents and the recently developed European Technical Specifications for Interoperability provide guidance in areas where the AREMA Manual is either silent or inapplicable. In addition, there have been a number of previously developed project-specific documents and documents from other sources that are relevant to the alignment design.

2.1.1 Project-Specific Technical References

- California High-Speed Train Project Basis of Design (20 December 2007)
- California High-Speed Train Project Design Criteria (19 March 2007)
- California High-Speed Rail Project Working Paper, Japan Railway Technical Service (JARTS) 2007

2.1.2 AREMA Manual

The primary orientation of the AREMA Manual is to provide guidance in the engineering of railroads moving freight at speeds up to 70 mph and passenger trains at speeds up to 90 mph with the exception of the still incomplete Chapter 17, High Speed Rail Systems. The statement at the beginning of each chapter will assist in understanding the scope, intent, and limitations of this document.

> "The material in this and other chapters in the AREMA *Manual for Railway Enginee*ring is published as recommended practice to railroads and others concerned with the engineering, design and construction of railroad fixed properties (except signals and communications), and allied services and facilities. For the purpose of this Manual, RECOMMENDED PRACTICE is defined as a material, device, design, plan, specification, principle or practice recommended to the railways for use as required, either exactly as presented or with such modifications as may be necessary or desirable to meet the needs of individual railways, but in either event, with a view to promoting efficiency and economy in the location, construction operation or maintenance of railways. It is not intended to imply that other practices may not be equally acceptable."

2.1.3 The European Union's (EU) Technical Specifications for Interoperability (TSI)

The Technical Specifications for Interoperability (TSI) are a set of standards required of all railroad systems in the European Union. For high speed railroad systems, they were first published as Council Directive 96/48/EC—Interoperability of the Trans-European High Speed Rail System. In the countries that are part of the European Union these standards have the force of law. The TSI are defined and published by subject matter, described as "Subsystems". Requirements of significance to a specific issue may require search of more than a single "Subsystem" document. The various subsystems are classified as either "structural" or "functional" as follows:

Structural Subsystems:

- Rolling Stock
- Infrastructure
- Energy

- Control and command and signaling
- Traffic operations and management

Function Subsystems:

- Maintenance
- Telemantics applications for passenger and freight services.

The TSIs relevant to this Technical Memo are:

- Infrastructure Subsystem, current version dated 19 March 2008 based on a Commission Decision of 20 December 2007;
- Rolling Stock Subsystem, current version dated 26 March 2008 based on a Commission Decision of 21 February 2008;
- Rolling Stock—Freight Wagons Subsystem, current version dated 8 December 2006 based on a Commission Decision of 28 July 2006.

The two Rolling Stock TSIs are relevant because certain necessary information is not in the Infrastructure TSI, but only referenced, to wit, the Infrastructure TSI states in paragraph 4.2.3: "The infrastructure must be constructed so as to allow safe clearance for the passage of trains complying with the High-Speed Rolling Stock TSI" and to be "set out on the basis of the GC reference kinematic profile and the minimum infrastructure lower parts gauge, both described in the High Speed Rolling Stock TSI." Then the Rolling Stock TSI in paragraph 4.2.3.1 states, "Rolling stock shall comply with one of the kinematic vehicle gauges defined in Annex C of the Conventional Rail Rolling Stock Freight Wagon TSI". The referenced Annex C provides dimensioned diagrams of both Static and Kinematic (Dynamic) outlines for all the referenced clearance requirements.

These diagrams are narrower than both American and Shinkansen equipment. The GC Outline is slightly taller than the Shinkansen equipment, but lower than any American equipment. All other TSI Outlines are lower than the GC Outline.

2.1.4 Other Technical References

The source for some portions of the design requirements can be found in the following other documents:

- Comité Européen de Normalisation – European Committee for Standardization (CEN standard)
- UIC – Design of new lines for speeds of 300 – 350 km/h – State of the art report (October 2001)
- Engineering studies in support of the development of high-speed track geometry specifications IEEE/ASME joint railroad conference (March 1997)
- Taiwan High Speed Railway Design Manual (2000)

2.2 LAWS AND CODES

In additional to the laws and standards relevant to any facility, there are a number of standards specific to railroad facilities that shall be applied. In case of disagreement among the requirements of these codes and standards and those in this document, the highest and best standard shall be applied.

The latest version of any referenced laws and codes shall be the one applicable.

2.2.1 United States National Standards

Federal Railroad Administration: The 200 series of requirements in Title 49 of the Code of Federal Regulations relate to railroads.

Occupational Safety and Health Administration (OSHA) Title 29 of the Code of Federal Regulations

Americans with Disabilities Act (ADA)

2.2.2 California Public Utilities Commission

Clearances adjacent to railroad tracks in California are governed in detail by two California Public Utilities Commission (CPUC) General Orders (GO's):

- GO 26: Clearances On Railroads And Street Railroads As To Side And Overhead Structures, Parallel Tracks And Crossings
- GO 118: Walkways Adjacent to Railroad Trackage. Provides specific minimum widths and locations for these walkway areas.

Even where not applicable, the GOs may provide useful guidance. Since these are legal requirements, they will, of necessity, form the Minimum Design Standards for the CHSTP.

2.2.3 Railroad Industry Standards

The Manual for Railway Engineering of the American Railway Engineering and Maintenance-of-Way Association (AREMA Manual), in particular the following chapters:

- Chapter 17: High Speed Rail Systems
- Chapter 28: Clearances

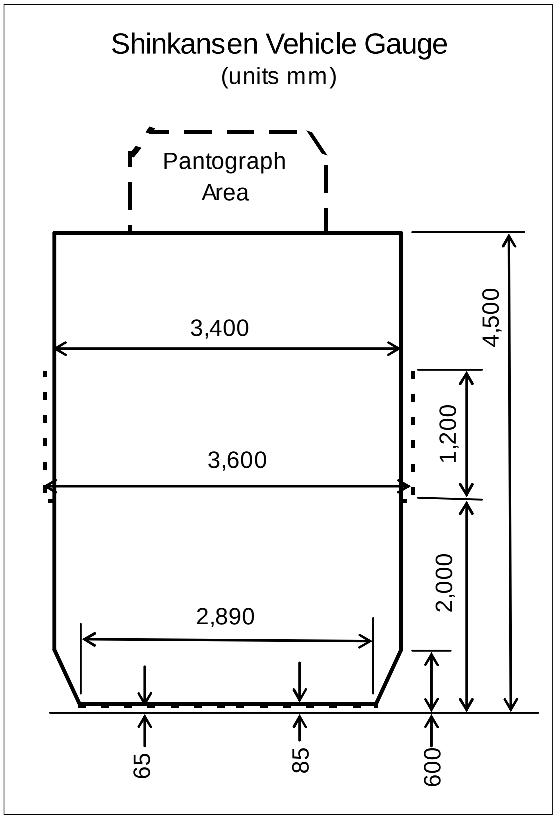
3.0 ASSESSMENT / ANALYSIS

Analysis of in-service high speed equipment results in the determination that all currently in-service equipment will be able to pass through a system that is designed and constructed to clear both the Shinkansen vehicle outlines and the TSI GC Gauge.

3.1 CURRENT HIGH SPEED EQUIPMENT STATIC GAUGES

3.1.1 Shinkansen Equipment

Figure 3.1.1: Shinkansen Static Gauge



The Shinkansen system Static Gauge, Figure 3.1.1, is a slightly modified simple rectangle. This is the Shinkansen Vehicle Gauge as it is given in their publications.

Figure 3.1.2 presents this Static Gauge in comparison to the currently constructed Shinkansen vehicles, both single level and bi-level.

The single level body height is 3650 mm = 11.98 feet. The bi-level height is 4493 mm = 14.74 feet, which is slightly higher than the noise reducing “ears” around the pantograph on the single level cars. The Shinkansen vehicle width is 3380 mm = 11.09 feet, which is 20 mm less than the width of the Static Gauge, hence the 3400 mm = 11.15 feet width of the Static Gauge. This difference is considered a manufacturing tolerance in the vehicle itself

Observation of Figure 3.1.2 shows that there are some areas where the Static Gauge does not closely follow the vehicle outline in three obvious locations.

First: There is no part of the vehicle within the 3600 mm wide section between 2000 mm and 3200 mm above the top of rail.

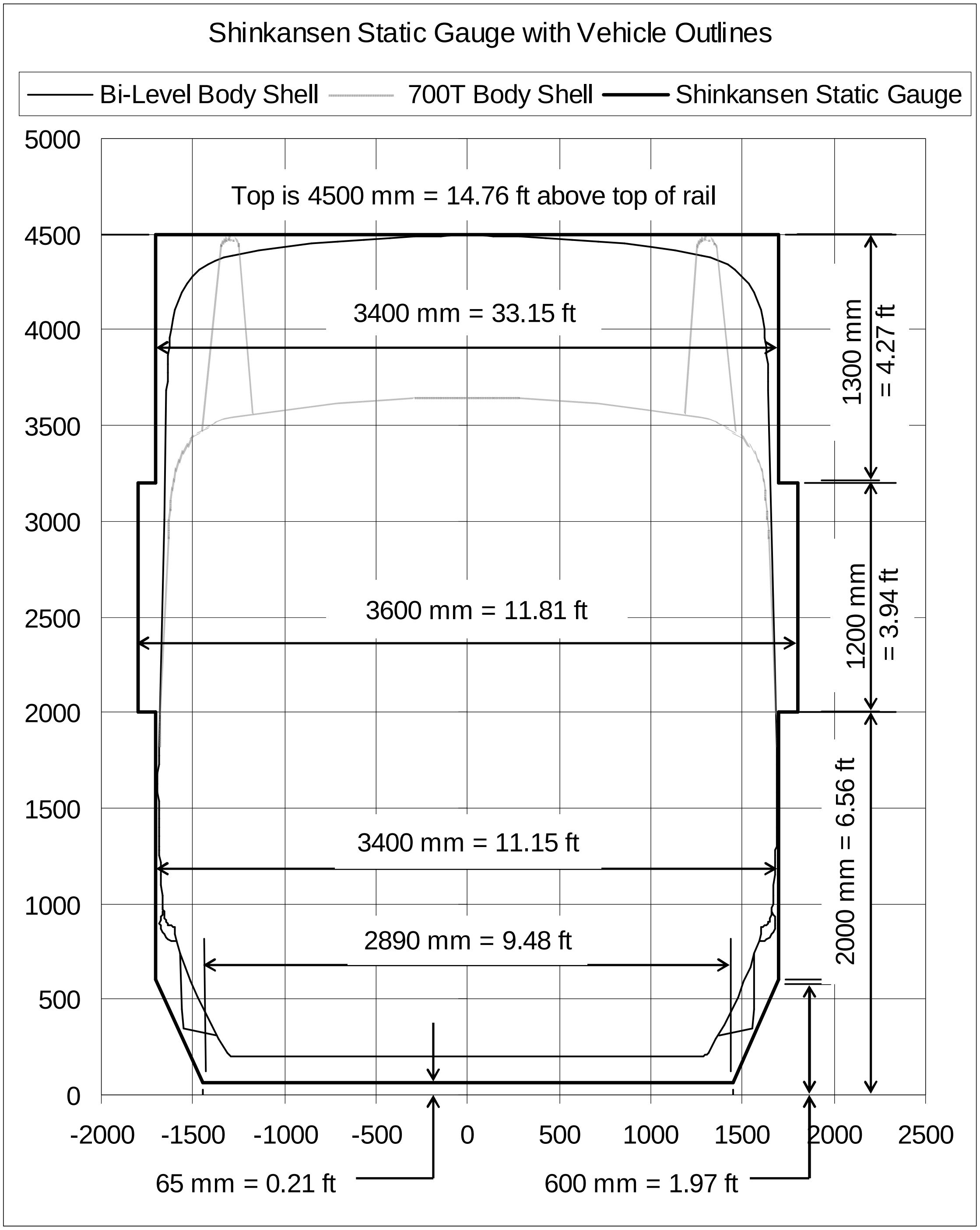
Second: The bottom zone taper is relatively small and falls well outside the vehicle itself.

Third: The square top corner. No other Static Outline has this shape, and there is no part of any Shinkansen vehicle, current or past in this space.

The widened area on the sides of the body: This area may relate to some feature in the earlier series of vehicle, but there is nothing in the current Shinkansen vehicles that enters this area, nor is there a similar feature in other vehicle outline. Therefore, this area will not be included in the final Static Gauge.

The Top and Bottom Corners: When it was attempted to apply the standard Shinkansen Vehicle Gauge to certain existing structures in the Taiwan High Speed Railway, it was found that there were both top corner and bottom corner difficulties with the gauge in the structures that were originally built for the Taiwan Railway as at the time they were constructed their use by standard gauge high speed trains was not anticipated. Analysis of the shape of the vehicle itself proved that these difficulties did not exist with the outline of the actual equipment. Therefore a modified Static Gauge was developed for Taiwan. This modified Static Gauge clears all currently manufactured single level Shinkansen Equipment, including that which may possibly be used in California. However, to clear bi-level Shinkansen coaches, the upper corner reduction cannot be as large as the reduction developed for the single level 700T coaches. A slightly smaller reduction in the upper corner is still desirable simply to prevent the section in curves from being artificially wide. See paragraph 3.2.1 and Figure 3.2.1 for the analysis of the bottom corner space needs and see paragraph 3.2.2 and Figure 3.2.2 for the top corner space needs.

Figure 3.1.2: Shinkansen Vehicle Outlines with Shinkansen Static Gauge



3.1.2 European Equipment – TSI Gauges GA, GB, and GC.

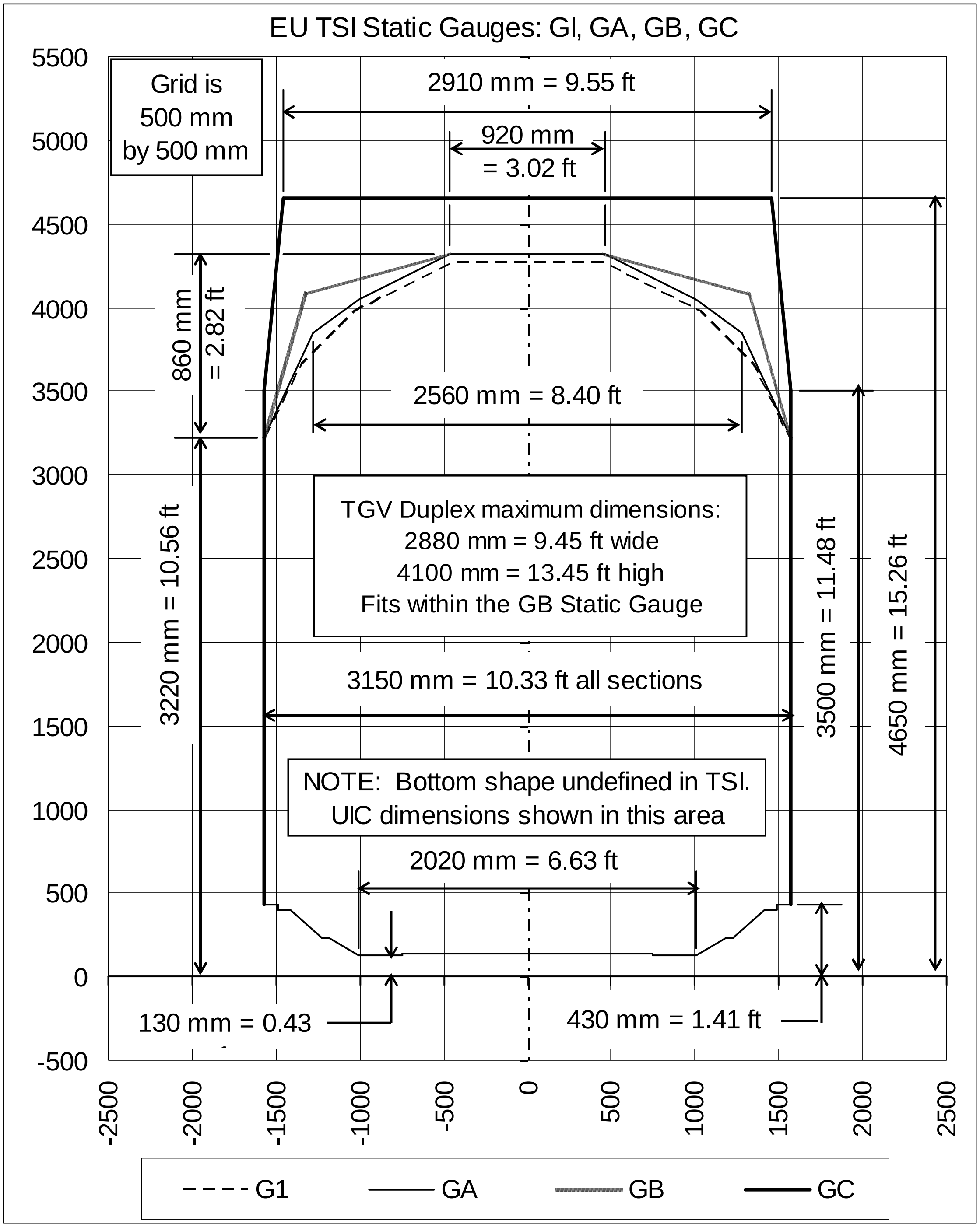
In EU Countries it is required that all new lines be constructed to pass the GC Gauge. The GC Static Gauge has a maximum width of 3150 mm (10.33 feet), the same as all other TSI Gauges. The GC Gauge maximum height is 4650 mm (15.26 feet) with a width of 2910 mm (9.55 feet) at that height. It is both taller and more square at the top than the other TSI gauges.

All European equipment fits within the limits of one of the smaller TSI Gauges, either the TSI GA or the TSI GB Gauge (Figure 3.1.3). The G1 and GA gauges give the apparent rounded top shape that is characteristic of much European equipment. The largest European high-speed equipment is the TGV

Duplex. At 2880 mm (9.45 feet) wide and 4100 mm (13.45 feet) high, it fits inside the TSI GA Gauge. However, to ensure TSI compliance, the GC outline will be used in developing clearances for the CHSTP.

The High-Speed Rolling Stock TSI states that "Rolling stock shall comply with one of the kinematic vehicle gauges defined in Annex C of the Conventional Rail Rolling Stock Freight Wagon TSI". Therefore, the clearance requirements of the various TSI Static Gauges are of interest only insofar as they influence the dimension of the Static Gauge that is inclusive of all currently available high speed trainsets.

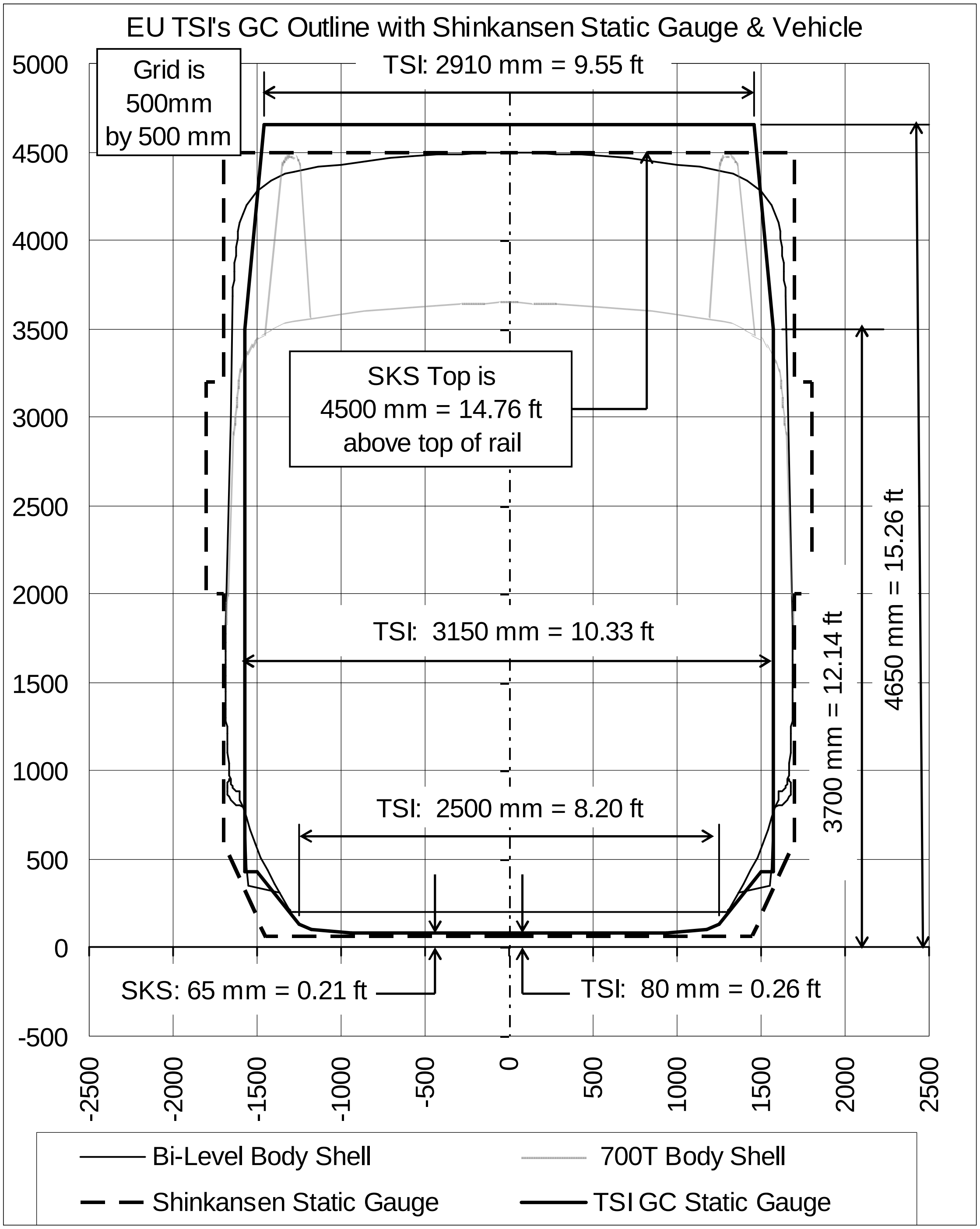
Figure 3.1.3: EU TSI Static Gauges G1, GA. GB, and GC



3.1.3 Static Gauge Comparisons: Shinkansen and TSI Gauge GC

All the TSI Gauges are narrower than the Shinkansen Gauge and equipment. Only the TSI GC Gauge is taller than the Shinkansen Gauge and equipment. When the TSC GC Static Gauge is overlain with the Shinkansen Static Gauge and vehicle outline (Figure 3.1.4), it is seen that the GC Gauge is only 150 mm (0.49 feet).taller than the Shinkansen Static Outline. Therefore, other than height, the Shinkansen Gauge is the governing outline for high speed equipment.

Figure 3.1.4: EU TSI Static Gauges GC Compared with Shinkansen Gauge



3.2 DESIGN STATIC GAUGE

These Shinkansen vehicle outlines and the TSI GC Static Gauge can be resolved into one Design Static Gauge; a Static Gauge for High-Speed Passenger Equipment sized to encompass the clearance requirements relevant to all currently available high speed equipment. The governing outline is primarily a combination of the Shinkansen Static Gauge in width and the TSI GC Outline in height.

3.2.1 Bottom Corner Space Requirements

The bottom corner static gauges vary considerably. Therefore, the various bottom corner outlines are overlaid and an outline developed that will pass all currently operating high speed equipment.

European Standards: The TSI does not provide any detailed bottom corner outline. The UIC does provide a very complex bottom corner outline in a similar manner to that in the AAR Plates.

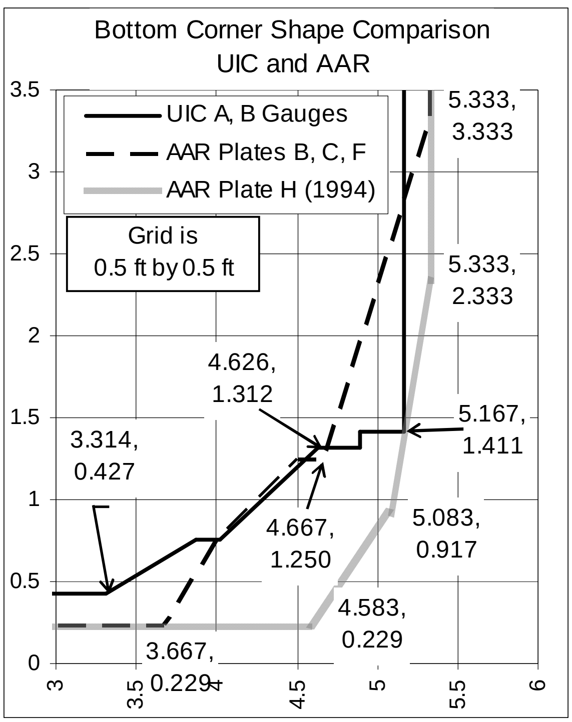
American Standards: The AAR Plates B to F have complex bottom corner outlines that restrict the lower corner area of the vehicle due to the past practice of building bridges with girders higher than the top of rail very close to the tracks.

Japanese Standards: The bottom corner of the Shinkansen Static Gauge went to the other extreme, having a large open space at the bottom corner in comparison to the actual car body outline.

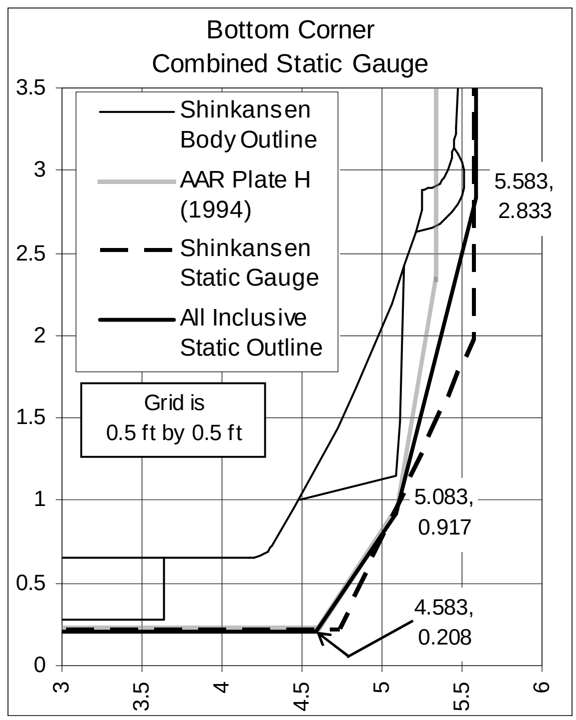
The CHSTP Static Gauges bottom corner area will not precisely follow the Shinkansen outline, but will be outside all currently manufactured Shinkansen equipment, which also makes this part of the outline outside all currently constructed European and American equipment.

Figure 3.2.1: Bottom Corner Shape Analysis

a. Overlay of Current Bottom Corner Outlines



b. Outline Inclusive of all High-Speed Outlines



3.2.2 Top Corner Space Requirements

For European coaches, including bi-level cars such as the TGV Duplex and the AGV Duplex, the Shinkansen Static Gauge as modified for Taiwan is sufficient, but there are two additional considerations. First, the Japanese have also built 4493 mm (14.74 feet) high bi-level cars for high speed service that fill more of the upper corner of the rectangular Static Gauge than the “ears” around the pantographs on the single level cars that defined the upper corner location of the modified Static Gauge used in Taiwan.

Second, the TSI GC Static Gauge is slightly higher than the Shinkansen Static Gauge. These shapes and Gauges are taken into consideration in the following analysis.

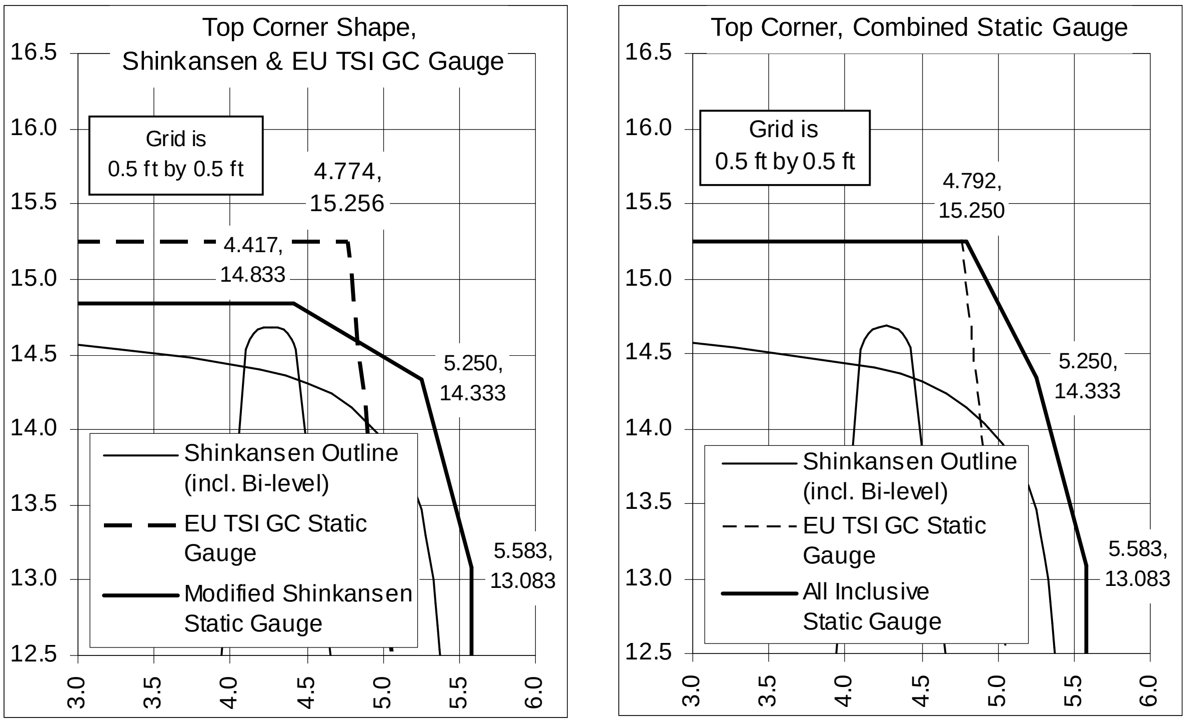
In 3.2.2.a, an overlay of the top corner of the various vehicle and static gauge outlines that need to be considered, consisting of the:

- Shinkansen Standard and Bi-Level Equipment Outlines
- Shinkansen Static Gauge modified to better represent body outline
- TSI GC Static Gauge

3.2.2.b presents the outline that encapsulates all these various vehicle static gauges.

Figure 3.2.2: Top Corner Shape Analysis for Minimum Static Gauge

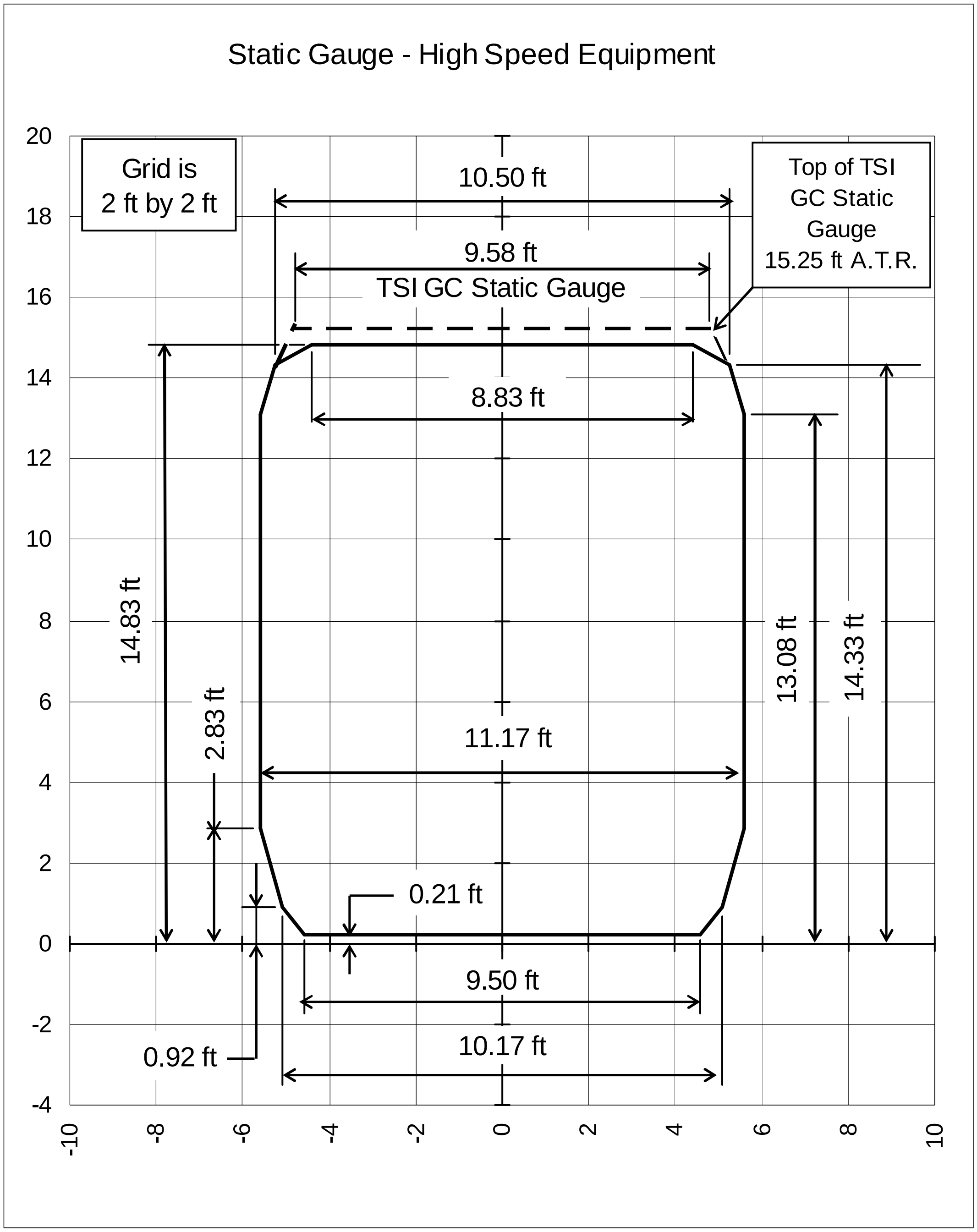
a. Overlay of Outlines under Consideration **b. Outline Inclusive of all High-Speed Outlines**



3.2.3 California High-Speed Passenger Equipment

Combining the conclusions of paragraphs 3.2.1 and 3.2.2, Figure 3.2.3 gives the outline to be used to develop the Dynamic Outline for High-Speed Equipment. The top portion derived from the TSI GC outline is shown dashed because its shift for its part of the dynamic outline is based on the TSI directions rather than the shifts and rotations defined for the Shinkansen equipment.

Figure 3.2.3: Static Gauge – High-Speed Equipment



Curvature and Superelevation: The cross section shall be widened for the effects of curvature and then the widened sections rotated about the point of rotation of the track for superelevation. The point of rotation is defined as the gauge corner of the inside rail of the curve. Therefore, the point of rotation is offset 2.354 feet from the track and vehicle centerline. Widening is very small on large radius curves (Figures 3.3.1 and 3.3.2). Rotated sections will be illustrated with the dynamic outlines.

3.3 EFFECTS OF CURVATURE AND SUPERELEVATION

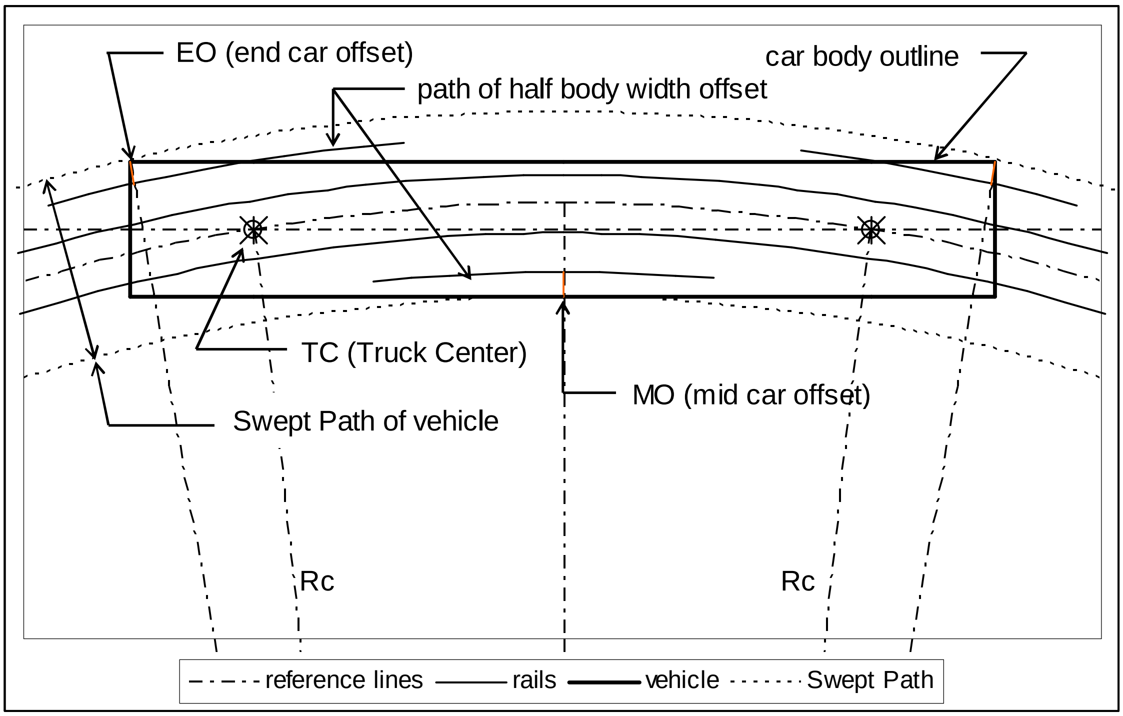
The Static Gauge is based on the vehicle dimensions plus small allowances for fabrication of the vehicle itself. The Dynamic Outline and Structure Gauge Outlines are derived from these vehicle outlines without consideration of the effects of curvature and superelevation. These effects are normally based on the Static Gauge, with consideration of such parameters as truck centers and end overhang beyond the trucks. Since the Dynamic Outline and Structure Gauges are developed from the vehicle as it is positioned on straight and level track, the effects of curvature and superelevation shall also be added to these dimensions. There is no need to add any tolerances to these effects, other than consideration of potential changes in superelevation as these enlargements are already in the Dynamic Outline and the Structure Gauge themselves.

3.3.1 Curvature

3.3.1.1 Theoretical Basis

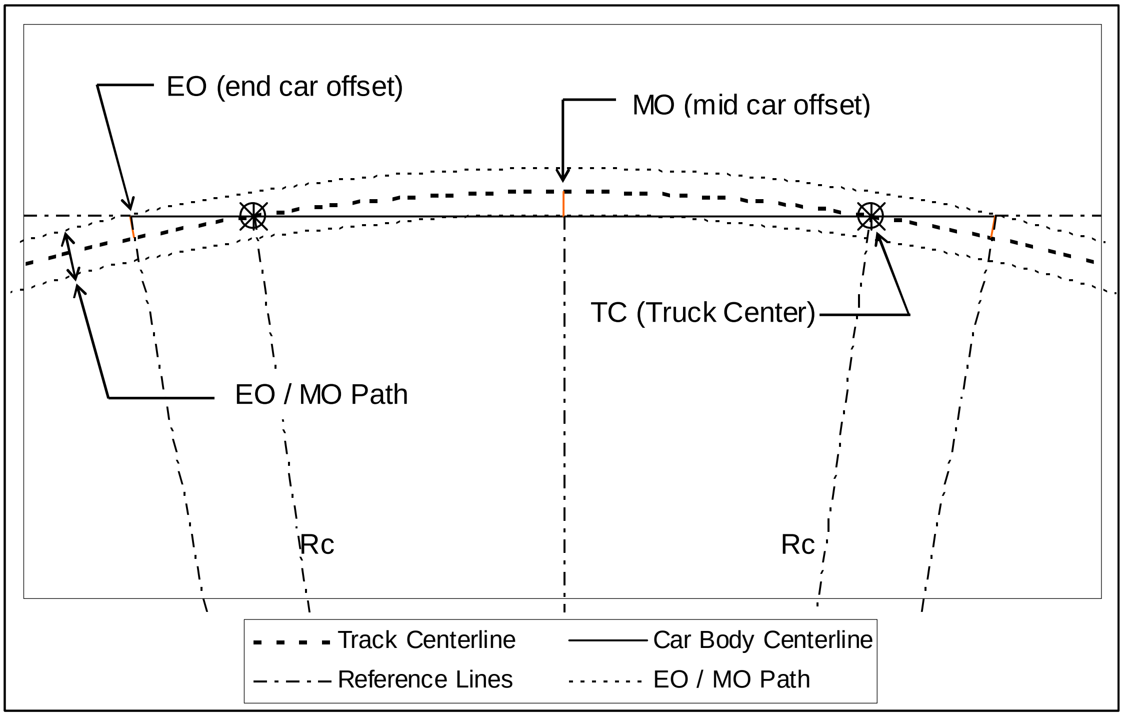
When a rectangular shape (the car body in plan view) is placed on an arc (a curve in the track), points on the long sides of the rectangle will not all be at the same distance from the arc. Therefore, allowance must be made for the additional width required on curves. The additional width to the outside is at the car body corners and the additional width to the inside is at a point half way between truck centers, as shown in Figure 3.3.1.

Figure 3.3.1: Vehicle on Curve



The complexity of the calculation can be simplified as the width of the car body can be neglected. Over the allowed range of curve radii, the half-width of the car body is around 2.00% or less of the curve radius, which makes it insignificant to the calculation. Therefore the car can be treated as a line in contact with the arc at two points rather than as a rectangle whose centerline is in contact with the arc at two points. The simplified situation is shown in Figure 3.3.2.

Figure 3.3.2: Curve Offset Calculation Schematic



As an example, the end car offsets and mid car offsets for a Shinkansen vehicle on 1000 and 500 feet radius curve are given in Table 3.1.1.

Table 3.3.1: Shinkansen Car Body Offsets on Curves, Exact Calculation

Radius	Offset Parameter	With Body in Calculation	Without Body in Calculation	Percentage Difference
500 feet	Mid-Car	0.8248 feet	0.8248 feet	0.00%
	End-Car	0.7728 feet	0.7905 feet	2.29%
1000 feet	Mid-Car	0.4122 feet	0.4122 feet	0.00%
	End-Car	0.3911 feet	0.3955 feet	1.14%

Note that the mid car offset values are exactly the same with or without consideration of body width, and that the outside calculation gives a larger value when the body width is neglected. Also, note that the percentage difference decreases as the radius in the calculation increases.

The effect of the axle spacing on the trucks was not included in the values shown in Table 3.3.1. The effect of axle spacing in the trucks is so small that axle spacing on the trucks reduces offset to the outside of the curve and increases it to the inside of the curve. At the minimum radius of 500 feet (152.4 meters) and 8.50 feet axle spacing, the additional offset is 0.0180 feet (5.50 mm). The offset values shown in Table 3.3.3 include the effect of axle spacing in the additional offset required toward the center of the curve, but do not include the effect of axle spacing in the additional offset required toward the outside of the curve.

Based on these guidelines, calculation of offsets based on centerlines may be made by the following formulae:

$MO = Rc – \mathrm{sqrt}(Rc^2 – (TC/2)^2)$

With axle spacing consideration: $MO = Rc – \mathrm{sqrt}(Rc^2 – (TC/2)^2) + Rc – \mathrm{sqrt}(Rc^2 – (AX/2)^2)$

$EO = \mathrm{sqrt}(Rc^2 – (TC/2)^2 + (BL/2)^2) - Rc$

All dimensions consistently in either inches or millimeters depending upon the measuring system used. TC is truck center distance. BL is length over body corners. AX is axle spacing in the trucks. Other factors as defined in Figures 3.3.1 and 3.3.2.

These offset distances are closely approximated by a simple formula in the form of Offset equals Constant divided by Radius. The Constant is specific to the truck center and body length dimensions of the vehicle and units of measurement. Derivation of these constants is in paragraph 3.3.1.2.

3.3.1.2 ADDITIONAL OFFSETS – VEHICLE BASED REQUIREMENTS

Calculation of curve related body movements requires the information given in Table 3.3.2.

Table 3.3.2: Car Body Dimensions for Curve Offset Calculations – Shinkansen

Characteristic	Shinkansen Coach	
	Feet	Millimeter
Body Length	80.38	24,500
Truck Centers	57.41	17,500
Ratio, TC/BL	0.714	0.714
Axle Spacing	8.20	2,500
Body Width	11.09	3,380

Table 3.3.3 provides the relationship between radius and offset necessary to develop a simple relationship between radius and car body offset.

Table 3.3.3: Shinkansen Car Body Curve Offsets, Exact Calculation and Derived Constant

Radius	**MO (inside offset)** MO = Rc – sqrt(Rc^2 – (TC/2)^2) + Rc – sqrt(Rc^2 – (AX/2)^2)	**Derived Constant** C = R * MO	**(EO) Outside Offset** EO = sqrt(Rc^2 – (TC/2)^2 + (BL/2)^2) - Rc	**Derived Constant** C = R * EO
Feet	Feet	R_{feet} * MO_{feet}	Feet	R_{feet} * MO_{feet}
10,000	0.0421	420.8	0.0396	395.8
5,000	0.0841	420.4	0.0791	395.4
2,500	0.1682	420.4	0.1583	395.6
1,000	0.4206	420.6	0.3955	395.5
750	0.5608	420.6	0.5273	395.4
500	0.8416	420.8	0.7905	395.3

Note that the maximum offset to the inside and to the outside are relatively close in value. This is ensured by having the truck centers set at around 0.7 to 0.72 of the total body length. This relationship minimizes the additional space required and enables the same values to be used both inside and outside, simplifying calculations. Note that the offset to inside is slightly larger than the offset to outside. Over time rail wear will also slightly reposition the vehicle toward the outside.

Shinkansen Equipment on Curves: Using Table 3.3.3 data and rounding, the Japanese Shinkansen vehicle requires an additional offset from centerline of:

EO (in feet) = MO (in feet) = 425 / R (in feet).

This is an offset, so it is half the increase in the body's "swept path" width. Note that for the 500 feet radius curve, the constant developed from Table 3.3.3 is in excess of the exact mid car offset calculation for by 0.0168 feet and of the exact end car offset calculation by 0.0511 feet. These differences may be regarded as insignificant.

European Equipment on Curves: The longest truck centers on the TGV articulated sets, 18,700 mm (61.35 feet). In UIC publications, the design passenger vehicle is based on truck centers of 19 meters (62.34 feet). For 19 meter truck centers, the calculated and rounded additional offset is:

MO (in feet) = 500 / R (in feet).

Although articulated units have no end overhang, the power units and other equipment will have ends that extend beyond the trucks, so additional offset to the outside will still be required, but it will be less than that for the Shinkansen vehicles.

Comparison Between Equipment Types: Although the TGV vehicle has longer truck centers than the Shinkansen vehicle, it is narrower than the Shinkansen vehicle, so that even at the minimum 500 feet radius the swept path of the Shinkansen vehicle will be wider than that of the TGV vehicle

3.3.1.3 CURVATURE OFFSET VALUES FOR DESIGN

General: Most systems use a simple standard formula in the form of O = C/R for the required additional offset adjacent to curves, normally using a "C" that gives an offset value somewhat greater than that required for the equipment normally operated. For example, the Shinkansen standard for offset gives an offset that is 25% greater than the calculated offsets for the Shinkansen standard coach.

Shinkansen: The widening to either side is calculated by

In metric units, Offset, both EO and MO (in millimeters) = 50,000 / R (in meters).

which is approximately

In US Customary units, Offset, both EO and MO (in feet) = 550 / R (in feet).

This offset is larger than that required for the standard Shinkansen vehicle or any other vehicle being considered for use in California. The constant in the metric formula appears to be a rounded value based on calculations using 20 meter (65.62 feet) truck centers. With an equivalent end overhang, the total vehicle length would be about 28 meters (91.86 feet) long.

EO and MO Values for Design: A convenient value to use in the formula for calculating the additional space requirement in "Desirable" and "Minimum" conditions is:

In US Customary units, Offset, both EO and MO (in feet) = 550 / R (in feet).

For the "Exceptional" condition, 500 may be used as the constant.

Entering and Exiting Curves: A precise calculation of the "swept path" of the vehicle in its transition into or out of a curve may be performed. This calculation is not necessary, as the usual object is to ensure sufficient space, not a precise need for additional space. For this purpose, the additional clearance is sufficiently achieved by beginning the transition from the unwidened section 75 feet into the straight track beyond the beginning of the spiral, or of the curve if there is no spiral and achieving the full needed additional offset not less than 25 feet before the beginning of the full arc. A precise "swept path" calculation is necessary if a station platform is affected. That issue will be covered in another document.

3.3.2 Superelevation Effects

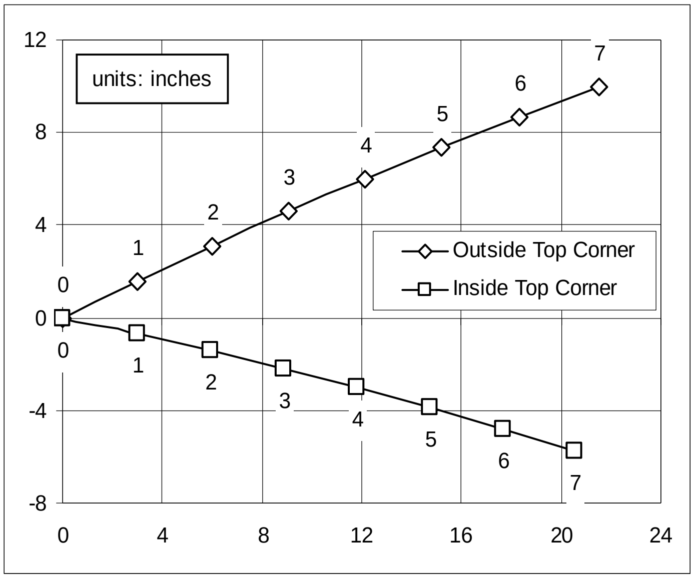
Points of Measurement on Tracks: Superelevation is measured, whether with a level board or by survey, by determining the relative difference in elevation between the highest point on the outside rail of the curve and the highest point on the inside rail of the curve. The distance between the points is normally considered as being track gauge plus rail head width. The high points are commonly slightly further apart than the centerline to centerline separation of the railheads due to the rail inclination toward the track center, but the distance is small and generally considered to be insignificant.

Gauge for standard track gauge is 56.5 inches, and rail head width is taken as being 3 inches. Thus the distance between points of measurement in the superelevation calculation is taken as being 59.5 inches (4.96 feet).

Method of Application: Superelevation is applied by holding the inside rail of the curve at the profile grade line and raising the outside rail to achieve the required superelevation. Therefore, the outside top corner of the vehicle goes up more than the inside top corner goes down.

Point of Rotation: The point of rotation is defined as the gauge corner of the inside rail of the curve. Therefore, the point of rotation is offset 2.354 feet from the track and vehicle centerline.

Figure 3.3.3: Shinkansen Car, Top Corner Movement with Superelevation



Superelevation Angle: The superelevation angle is:

$$\text{Angle} = \arcsin(Ea / G + HW)$$

where Ea is superelevation, G is track gauge and HW is head width of the rail. Therefore, the angle is normally expressed as:

$$\text{Angle} = \arcsin(Ea_{inches} / 59.5)$$

Figure 3.3.3 plots the movements of the top corners of the Shinkansen Static Gauge in one inch increments of superelevation as an example. This shape will not be the design outline for the CHSTP, but, since it is a simple rectangle, it is used as an example of the effect of rotation on the position of the top outside corner of the vehicle. Widening of the swept path is also neglected in this figure. See the movements of the various Dynamic Outlines for movements to be considered in design.

3.4 DYNAMIC ENVELOPES

The design Static Gauge is developed into an appropriate Dynamic Envelope by taking the anticipated limits of equipment movement and adding these values to the Static Gauge. The limits on these lateral, vertical and rotational movements are part of the equipment design analysis, but this work has yet to occur. As it was with the Static Gauge, the Dynamic Envelope is a combination of Shinkansen and TSI requirements. Specifically, it is based on the Shinkansen Dynamic Envelope in width and the TSI GC "Kinematic Vehicle Gauge" in height.

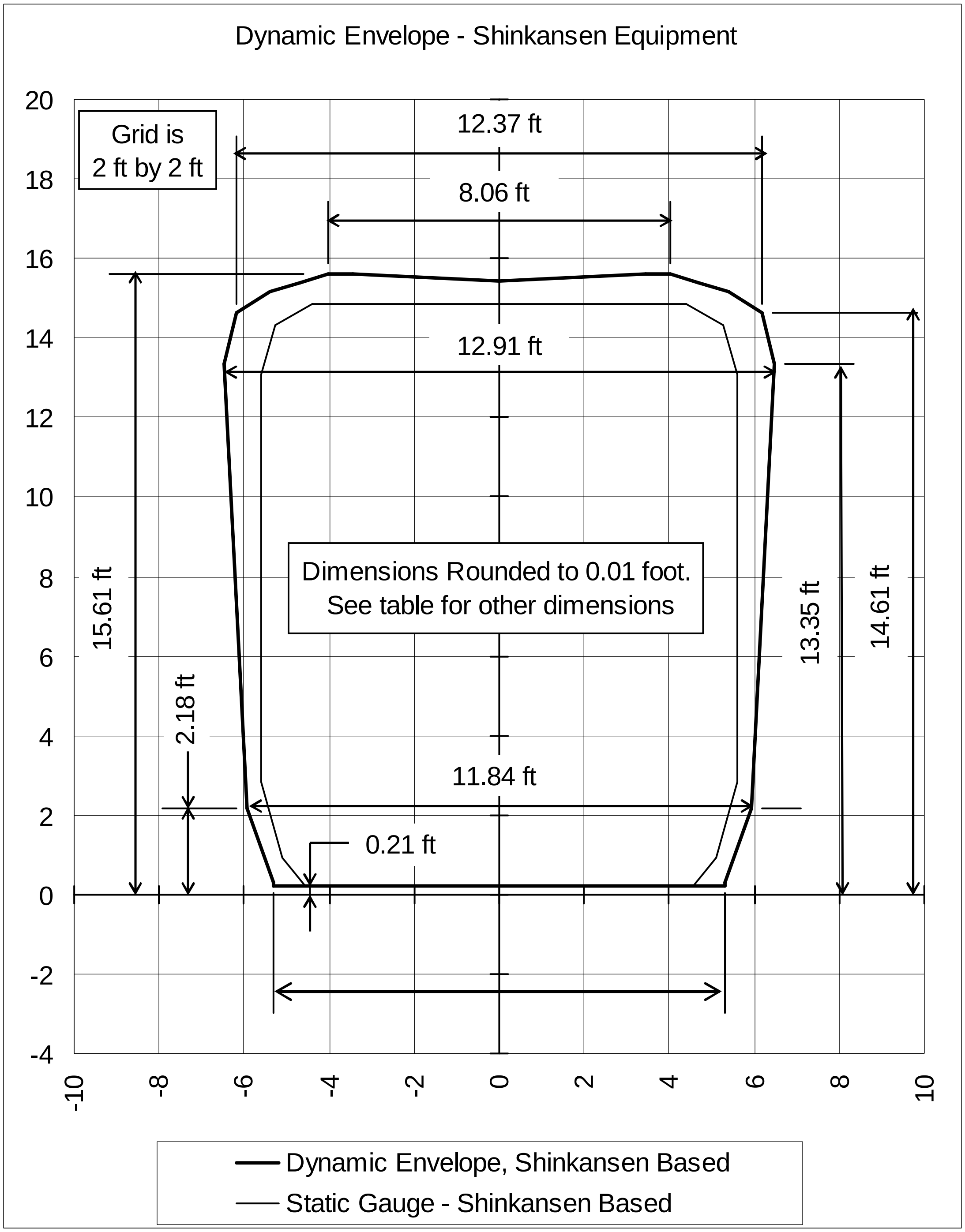
3.4.1 Shinkansen Dynamic Envelope

A very thorough analysis of the movements of the Shinkansen equipment was performed as a part of the equipment procurement contract for the Taiwan High Speed Railway. The design motions were: lateral displacement, 43 mm (1.69 inch); roll angle, 2.24 degrees; and vehicle yaw, 19 mm (0.75 inch) determined by placement of the wheels of the vehicle against opposite rails to produce maximum end of vehicle car body offset. Various suspension failures and other motions, vertical, horizontal and rotational were modeled, resulting in maximum upward deflections of 146 mm (5.75 inches) and maximum downward deflections of 88 mm (3.46) inches. The motions developed in this analysis will be applied to the High-Speed Static Gauge (Figure 3.2.3)

Since the Dynamic Envelope is to be used to develop the Structure Gauge, allowance for track deviations shall also be included. Track deviations are assumed as being of 1 inch horizontal and vertical plus a cross level error of 0.5 inches. This cross level error adds 0.50 degrees to the total rotation angle. These track allowances are excessive for high speeds. However, there is no need to reduce them for high speeds as the need to provide additional space around the vehicle as speeds increase will be of more significance than any reduction in vehicle dynamic envelope. With these additions for track deviations, the dynamic Outline movements to be used in development of Structure Gauge are:

- Lateral expansion: 3.5 inches
- Downward expansion: 4.5 inches
- Upward expansion: 6.75 inches
- Angular movement: 2.75 degrees – rotation point: on vehicle centerline at 16.5 inches above top of rail

Figure 3.4.1: Dynamic Envelope – Shinkansen Equipment



3.4.2 European Equipment Dynamic Envelope

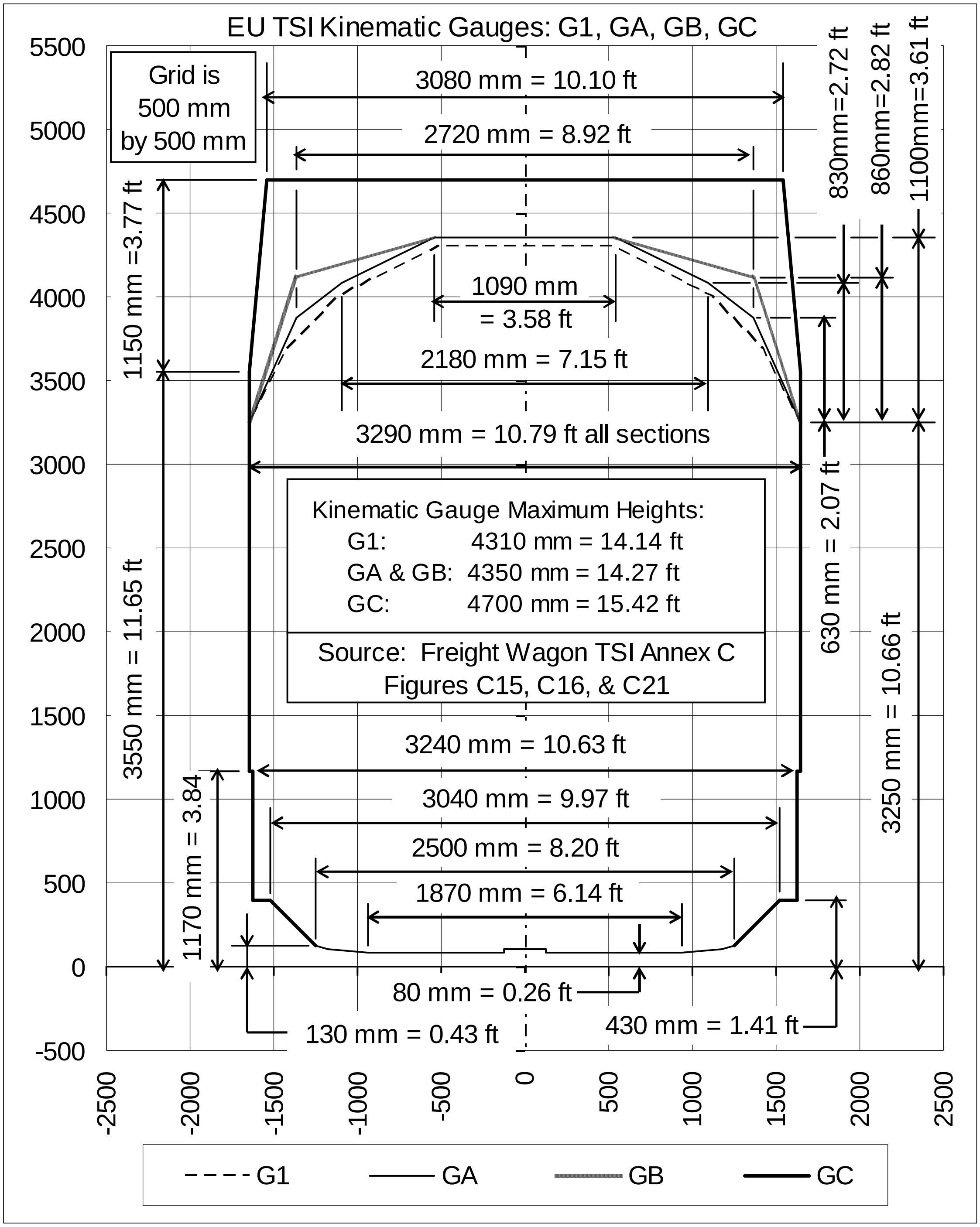
The EU Infrastructure TSI states (in 4.2.3) that clearances shall be based on the:

> GC reference kinematic profile and the minimum infrastructure lower parts gauge, both described in the High-Speed Rolling Stock TSI.

The High Speed Rolling Stock TSI requirement consists of a reference to Annex C of the Conventional Rail Rolling Stock Freight Wagon TSI which states the following:

- "C.3. In 1991 the decision was taken that the regulations for static gauge should no longer be used for construction of wagons."
- "C.3.2.1 *Part common to all vehicles*: The G1 Kinematic reference profile takes into account the most restrictive lineside structure positions and track center distances in Continental Europe."
- "C.4 GA, GB, GC VEHICLE GAUGES: By comparison with the G1 gauge, the GA, GB, and GC gauges are larger in the upper part."

Figure 3.4.2: EU TSI Kinematic Gauges (Dynamic Outlines) G1, GA. GB, and GC

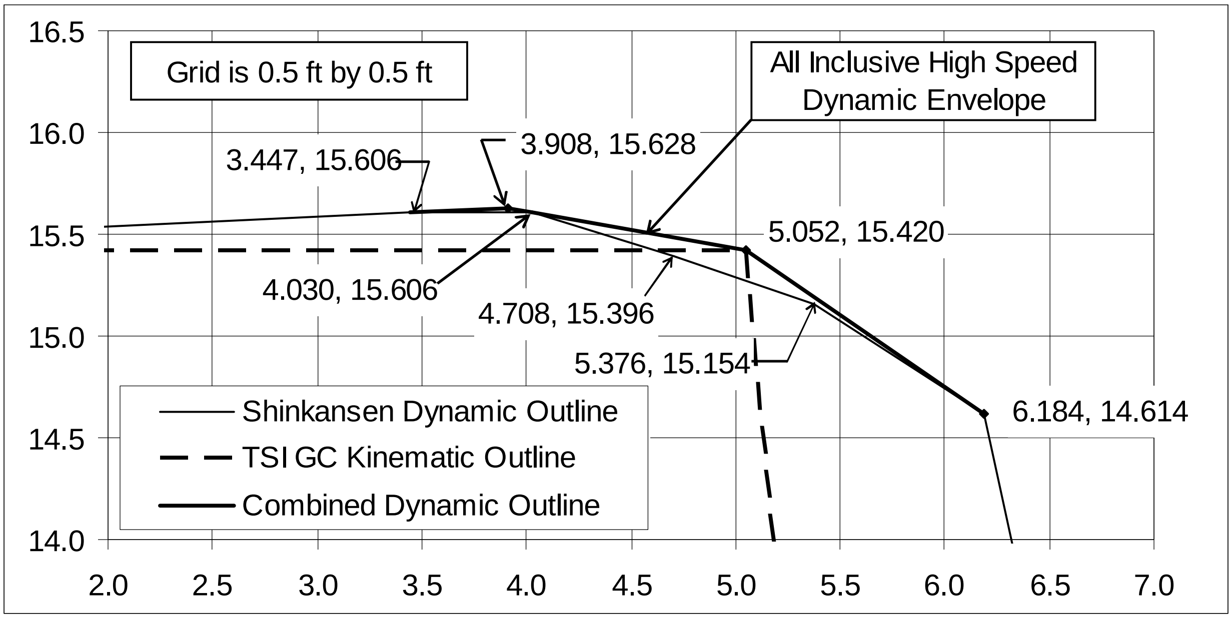


Other Outlines described in this publication are referenced in discussions concerning equipment. For example, Alstom has stated that the AGV Duplex "fits inside the UIC G2" envelope. This G2 Gauge is found in Annex C, Figure C22 (Static Gauge) and Figure C23 (Kinematic Gauge). At its maximum height of 4680 mm (15.35 feet),and width of 1570 mm (5.15 feet), it is completely inside the GC Gauge Other than Gauges for systems having broad gauge tracks, Spain and Portugal for example, all other Gauges are variations of Gauges, G1, GA, GB, and GC. Only those four gauges are shown in Figure 3.4.2, and only the GA, GB, and GC Gauges are dimensioned.

3.4.3 Development of a Combined Outline

Since the Shinkansen vehicle envelope is the largest in all dimensions except height, this combined outline will be based on the combination of the Shinkansen Dynamic Envelope and those points on the TSI GC envelope that lie outside that expanded Shinkansen envelope as shown in Figure 3.4.3

Figure 3.4.3: Top Corner Relationship between Shinkansen and TSI GC Dynamic Outlines



3.4.4 Dynamic Outline

3.4.1.1 On Straight Tracks

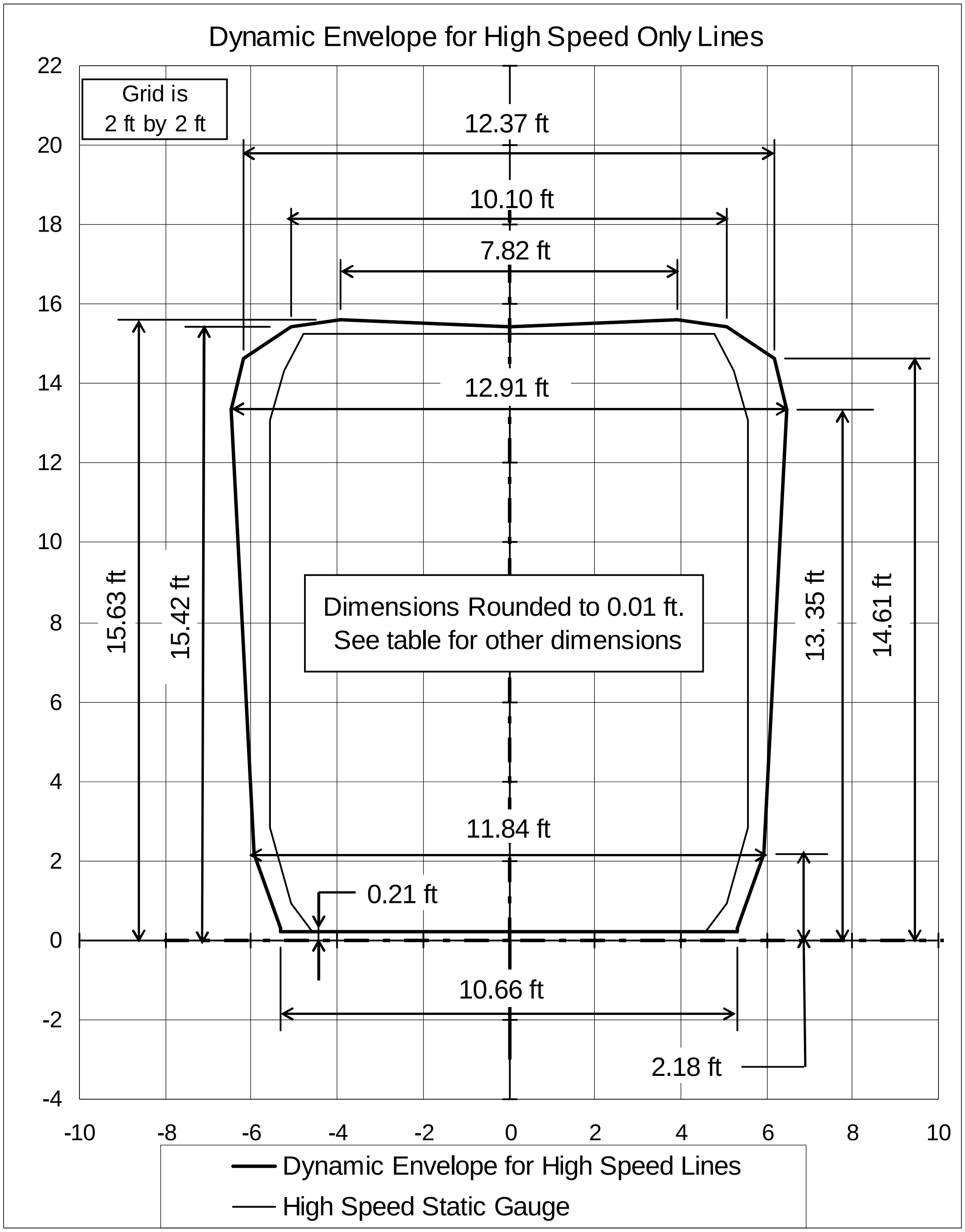
The points around the Dynamic Outline that will pass all current High-Speed Equipment is shown in Table 3.4.1 and illustrated in Figure 3.4.4.

Table 3.4.1: Dynamic Envelope – For High-Speed Passenger Tracks

Feet		millimeters (for reference)	
X (from centerline)	Y (above top of rail)	X (from centerline)	Y (above top of rail)
0.00	0.21	0	64
5.33	0.21	1624	64
5.92	2.18	1804	663
6.46	13.35	1968	4069
6.18	14.61	1885	4454
5.05*	**15.42***	**1540***	**4700***
3.91	15.82	902	4846
0.00	15.44	0	4706

* Corner of TSI GC Kinematic Outline

Table 3.4.4: Dynamic Envelope – For High-Speed Passenger Tracks



3.4.1.2 CURVATURE EFFECTS

The combined Dynamic Envelope cross section shall be widened for the effects of curvature and then the widened sections rotated about the point of rotation of the track for superelevation as described in Section 3.3. Since the widening due to the effects of all car movements in relation to the track have been included in the Straight Line Dynamic Outline case, the curvature effects are the same as described for the Static Gauge. Therefore, only the formula EO and MO (in feet) = 550 / R (in feet) Desirable and Minimum or EO and MO (in feet) = 500 / R (in feet) need be applied. See Table 3.4.2 for a few examples:

Table 3.4.2: Widening for Curvature Effect

	Desirable & Minimum 550 / R(feet)		Exceptional 500 / R (feet)	
Radius (feet(	Widening per side (feet)	Full section max. width (feet)	Widening per side (feet)	Full section max. width (feet)
50,000	0.011	12.94	0.010	12.93
10,000	0.055	13.02	0.050	13.01
5,000	0.110	13.13	0.100	13.11
1,000	0.550	14.01	0.500	13.91
750	0.733	14.38	0.667	14.25
500	1.100	15.11	1.000	14.91

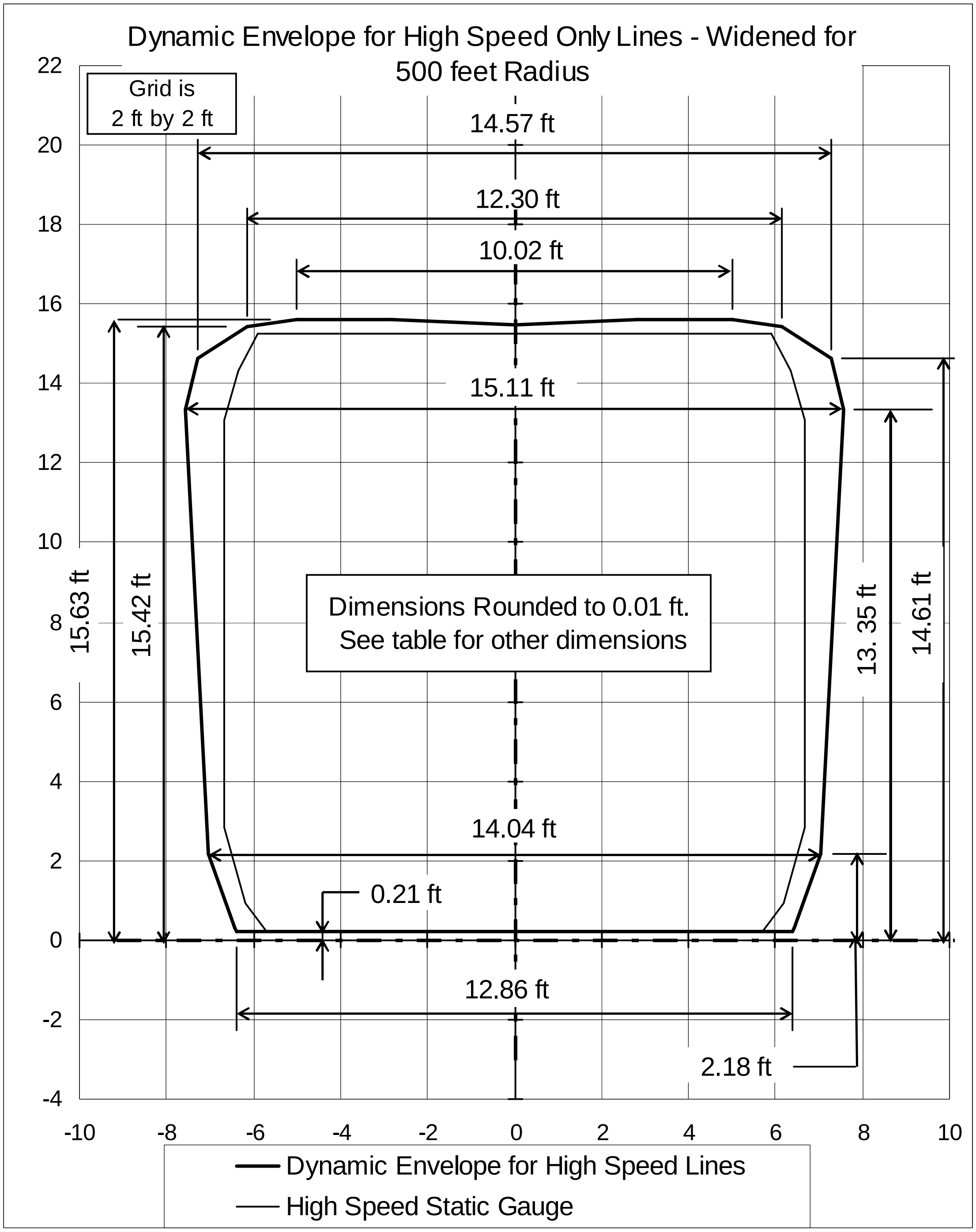
Widening under 0.05 feet may be neglected. The widening applicable to all points on the outline is shown in Table 3.2.3.

Table 3.4.2: Dynamic Envelope – For 500 feet Radius Curve

Desirable/Minimum (feet)		Exceptional (feet)	
X (from centerline)	Y (above top of rail)	X (from centerline)	Y (above top of rail)
0.00	0.21	0.00	0.21
6.43	0.21	6.33	0.21
7.02	2.18	6.92	2.18
7.56	13.35	7.46	13.35
7.28	14.61	7.18	14.61
6.15*	15.42*	6.05*	15.42*
5.01	15.82	4.91	15.82
0.00	15.49	0.00	15.49

- Corner of TSI GC Kinematic Outline

Figure 3.4.5: Dynamic Envelope – High-Speed Vehicle Widened for 500 foot Radius Curve



3.4.1.3 SUPERELEVATION EFFECTS

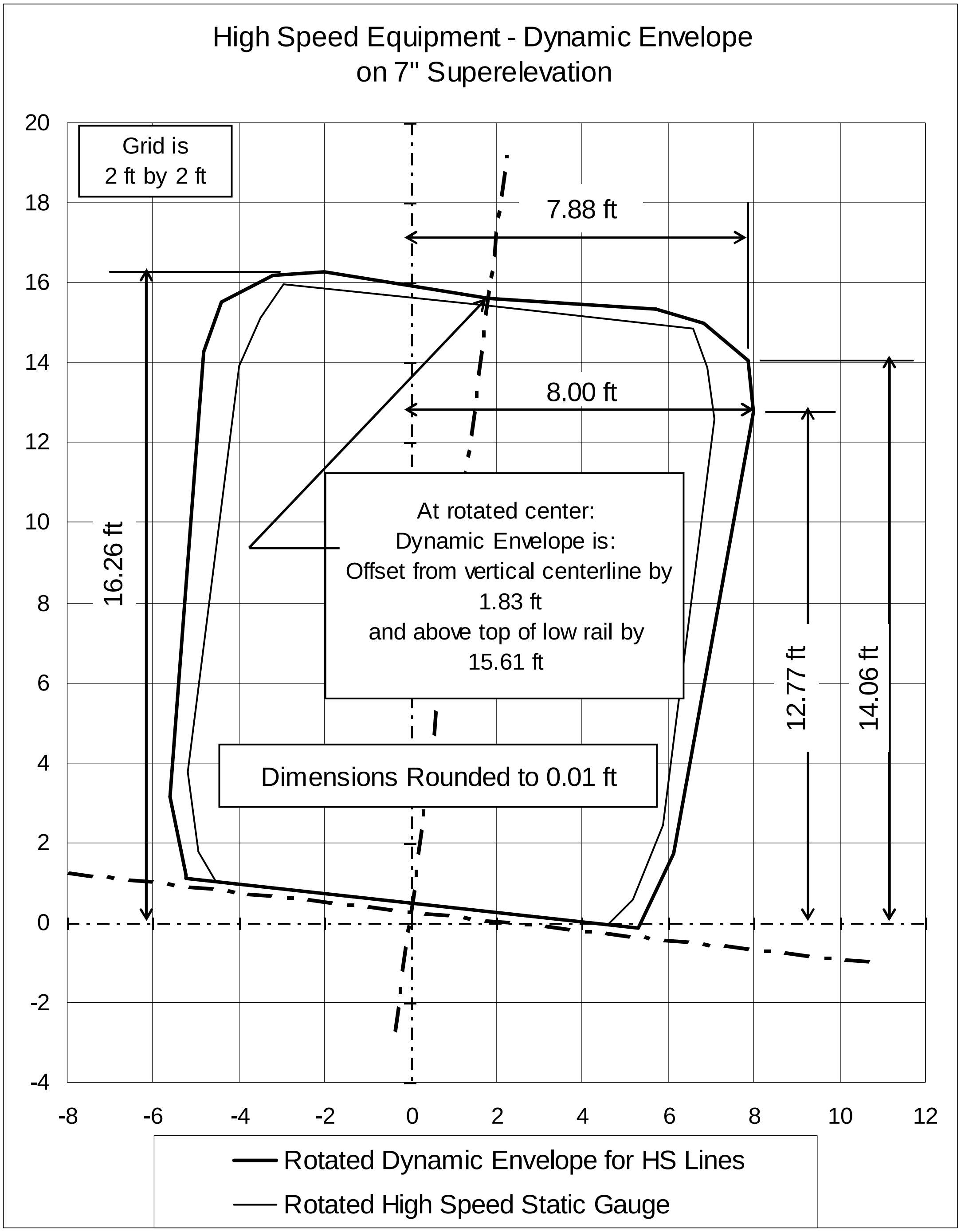
After the vehicle section is widened for the effect of radius, the widened section shall then be rotated for the effect of superelevation. The point of rotation is defined as the gauge corner of the inside rail of the curve. Therefore, the point of rotation is offset 2.354 feet from the track and vehicle centerline. Widening is minimal on large radius curves. Rotated sections for maximum superelevation and for the combination of small radius and maximum superelevation are illustrated in Figures 3.4.6 and 3.4.7. Sections for other values of superelevation and radius shall be developed as needed.

When calculating the angle for rotation of the section, the chord is not track gauge alone, but track gauge plus rail head width. Therefore the formula is:

Ea angle = arcsin (Ea in inches / 59.5 inches)

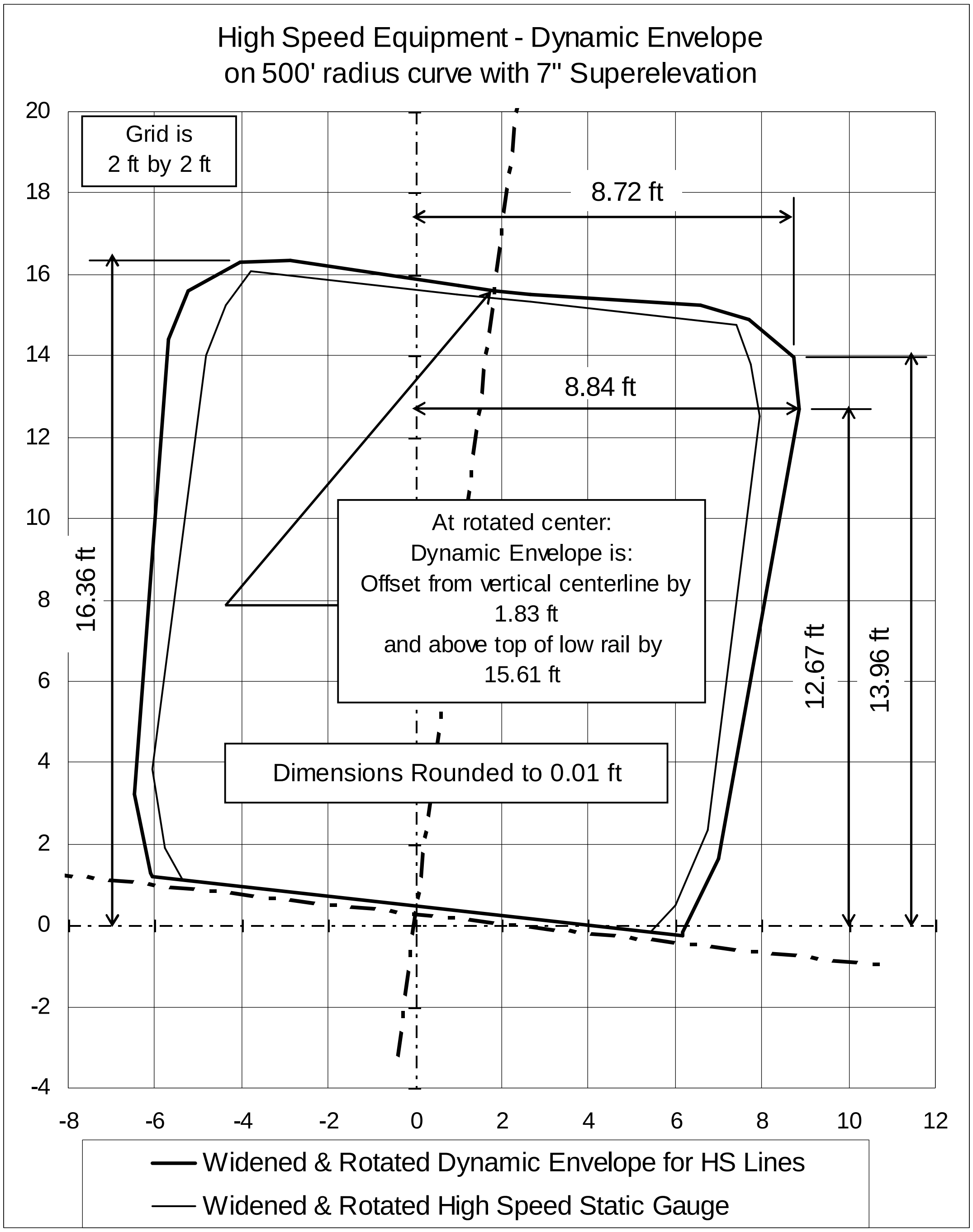
Figure 3.4.6 shows the Dynamic Envelope as it would appear on a curve with 7 inches of superelevation. The effect of the vehicle end offset / mid car offset is not included in this outline, but should be added to the Dynamic Envelope before it is rotated for application to curves with smaller radii.

Figure 3.4.6: Dynamic Envelope –High-Speed Vehicle on Superelevation without Curve Widening



Main line curves in the high speed sections will of necessity be of such large radius that the mid-car and end-car offsets will be negligible. However, on station connection tracks and in other lower speed areas, the mid-car and end car swings will need to be considered. The extreme case would be that of a curve with 500 feet radius and a superelevation of 7 inches. This case is unlikely to occur.

Figure 3.4.7: Dynamic Envelope Rotated for Superelevation and Widened for Effect of 500' Radius



3.5 STRUCTURE GAUGES

Structure gauges define the closest location of any facility near the track. Without being excessive, the structure gauge should avoid being unnecessarily close to the vehicle. These structure gauges relate only to the vehicle itself. Typical cross sections for bridges and tunnels, considerations for aerodynamics, electrification facilities, etc will be in other Technical Memos and are outside the scope of this TM. For discussion and background on various clearance outlines and structure gauges, see the Appendices.

3.5.1 Development of Size Requirements

3.5.1.1 HEIGHT OF STRUCTURE GAUGE, EXCLUDING ELECTRICAL ALLOWANCES

CPUC GO26D does not provide any useful guidance in this area. It requires an overhead clearance of not less than 14.00 feet above the top of rail for passenger only lines without addressing the allowable height of vehicle. This is lower than the dynamic envelope of the equipment that must be cleared.

The Japanese Shinkansen Structure Gauge limit is 4600 mm (15.09 feet) above top of rail, with space above that line reserved for electrical equipment. This is only 100 mm (0.33 feet) above the height of the vehicle itself, and is within the Shinkansen Dynamic Envelope. The top of the German structure gauge is 4900 mm (16.08 feet) above the rail, 200 mm (0.66 feet) above the top of the GC Kinematic Envelope.

The Structure Gauge developed in this Technical Memo is of sufficient height to clear the various high speed trainsets under consideration and no more. Therefore, it is highly desirable that overhead features be located so as to permit vertical clearance increases in the future to be relatively inexpensive.

3.5.1.2 WIDTH OF STRUCTURE GAUGE

Based on the discussion in subsection 3.5.1.5, a clearance from centerline of 8.08 feet would satisfy CPUC GO26D. Since this dimension provides no allowance for construction tolerances, curves and other factors, a larger dimension shall be used. In the Taiwan High Speed Railway, the minimum clearance to a fixed object along the main tracks is set at 2,500 mm (8.50 feet) without a walkway and 3,300 mm (10.83 feet) with a walkway. On viaducts the minimum offset to the trackside edge of the walkway is larger than 2500 mm, as the walkways are set beyond the catenary poles, which were set with their track side no closer than 3050 mm (10.01 feet) from the nearest track center. The 3050 mm catenary pole offset cleared the Dynamic Outline of the vehicle in all cases of superelevation and radius. In tunnels and adjacent to wall where fixtures such as lights, fire lines, signs, and cables are inside the structure, an allowance of 300 mm (0.98 feet) is added to the minimum offset. This dimension is not sufficient for all facilities.

The Structure Gauge width from centerline shall be no less than 8.50 feet with an additional allowance of 1.50 feet to walls or the inside of tunnels for fire water lines, signs, lights, and other fixtures to be mounted on the wall or tunnel face, giving a total offset of 10.00 feet. The width selected is slightly larger than that necessary in order to avoid the need to widen the section on large radius curves. Widening of the section for small radius curves and the rotation of the section for superelevation is discussed in Section 3.5.3.

3.5.1.3 SPACE FOR ELECTRIFICATION FACILITIES

All sections exclude any consideration for the space required for the Overhead Contact System (OCS). The space required for the OCS will be in another Technical Memo. The Bottom of the space required for the OCS shall be the top solid line shown in Figures 3.5.3 through 3.5.13. The dashed lines above the top of the vehicle structure gauge between which the space labeled as “Space for Overhead Contact System” is indicative only. See TM 3.2.3 - Pantograph Clearance Envelope, and TM 3.2.1 - OCS Requirements for definitive space requirements in this zone.

The presumed contact wire elevation in this analysis is 17.41 feet.

3.5.1.4 SPACE FOR UTILITIES AND OTHER FACILITIES

There will be the need to place various utilities and other facilities along the tracks. The offsets to wall and other major constraining features must permit placement of such items. For this purpose, the structure gauge outlines have an inner dashed line showing the placement limit for such features as, including but not necessarily limited to the following:

- Conduits and cables
- Fire water lines
- Catenary system
- Signs and markers
- Signals and train control devices

3.5.1.5 WALKWAYS

A walkway space shall be provided along at least one side of every track. Walkways serve two primary purposes:

- Pathways and refuge areas for employees on the trackway for maintenance, inspection, or other duties.
- Passenger evacuation in case of the need to detrain passengers outside stations

Where catenary poles are located adjacent to a track, the track side edge of the walkway may be set on the side of the catenary pole away from the track. Otherwise, the offset to the trackside edge of the walkway shall be beyond the Space for Utilities portion of the structure gauge.

Regulatory requirements include but are not necessarily limited to the following:

- CPUC GO 26 D requires, "Minimum side clearances of railroad and street railroad tracks which are not used or proposed to be used for transporting freight cars shall be thirty (30) inches from the side of the widest equipment operated."
- CPUC GO 118 requires walkways to be no less than 2.00 feet wide. But, this space is defined with its far edge being no less than 8.50 feet beyond the track centerline which puts the near side of the walkway no less than 14 inches clear of any railcar, making the far edge of the walkway effectively 3.17 feet clear of any obstruction. The walkway width is increased to 3.00 feet around switch stands. No clear height is defined. The walkway requirement in this GO is based on employee safety.
- OSHA Standards (29CFR 1910, paragraph 36) requires exit routes to be "the width of the exit and exit discharge must be at least equal to the width of the exit access" but not less than 2.33 feet wide at all points and not less than 7.50 feet high, but permitting projections down to not lower than 6.67 feet above the floor elevation.
- The <u>ADA Accessibility Guidelines for Buildings and Facilities</u> requires a minimum walkway width of 3.00 feet. The necessity to provide this width adjacent to a track may be debatable. However, a level surface of no less than this width should be provided for any walkway which may possibly be used for passenger evacuation.

Considering all these requirements, the walkway envelope should be defined as follows:

- The walkway width should be not less than 3.00 feet and shall be no less than 2.75 feet. This width shall prevail from walkway surface to a point 6.00 feet above the walkway surface. Above that height, the section may taper inward on the track side where the track is superelevated.
- The vertical walkway space shall be no less than 7.50 feet above the walkway surface or top of rail elevation, whichever is higher
- The walking surface shall be no less than 0.50 feet wider than the walkway envelope so as to provide the widest practical walking surface for evacuation purposes. Normally this additional width may be on the side toward the track.

Where speeds are less than 50 mph, the offset to the trackside edge of the walkway envelope may be reduced by 1.00 feet. In the case of walkways in tunnels or adjacent to walls, sufficient additional offset for mounting of pipes and other fixtures shall be added to ensure that these features do not encroach into the walkway allowance.

The following figures, Figure 3.5.1 and 3.5.2 illustrate the walkway envelope and its relationship to the Structure Gauge for other features for straight and superelevated tracks respectively. On superelevated curves, the profile of the alignment is defined by the top of the inside rail and all superelevation is provided by raising the outside rail of the curve. See paragraphs 3.5.2 and following for the development and explanation of other features in the Structure Gauge.

The vehicle side dashed diagonal line between walkway elevation line and solid line that is in the plane of the top of rails is not intended to be the actual location of the track side edge of walkway but only to define the closed approach of any feature to the track.

Figure 3.5.1: Walkway Detail, Track without Superelevation

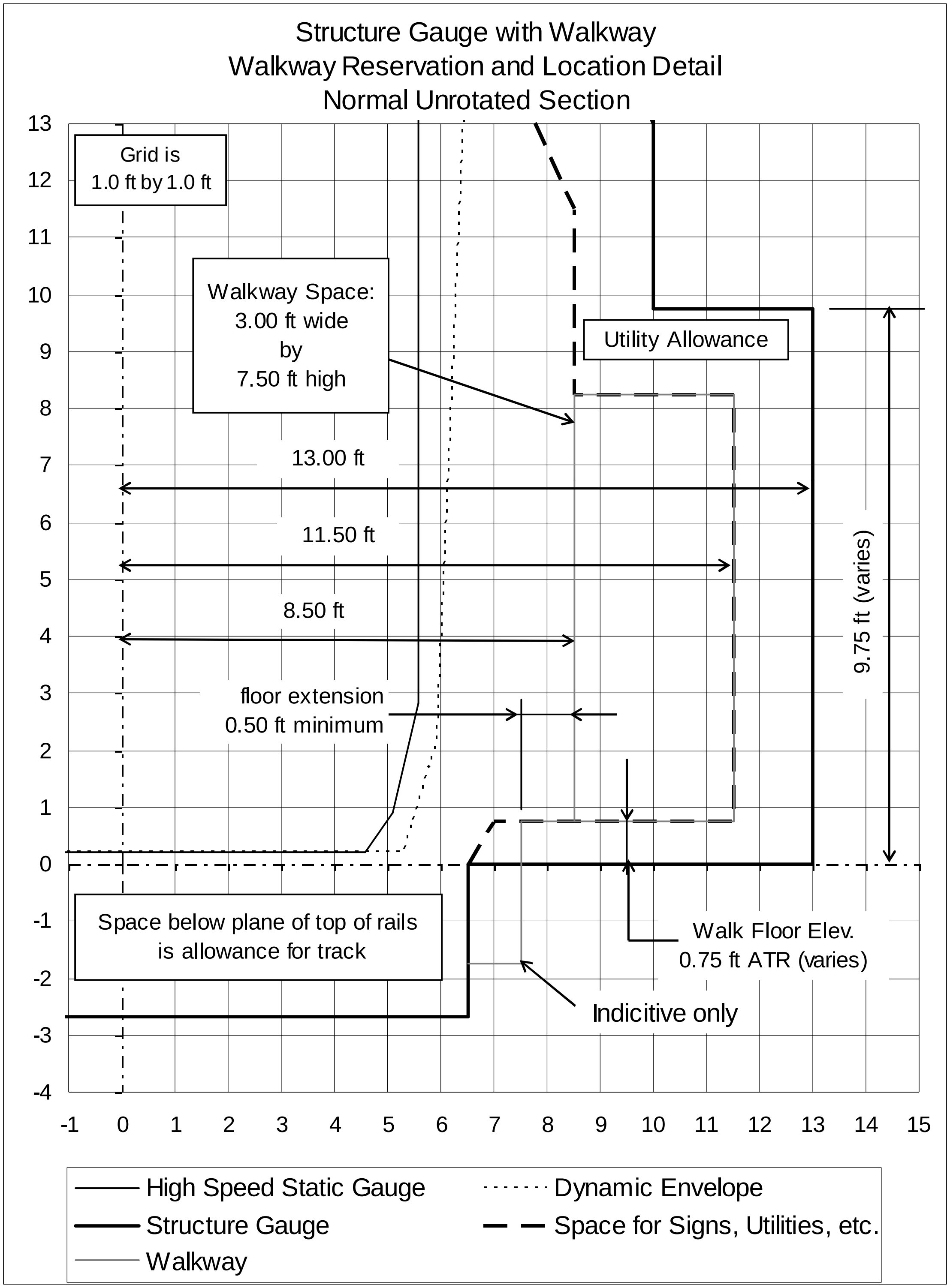
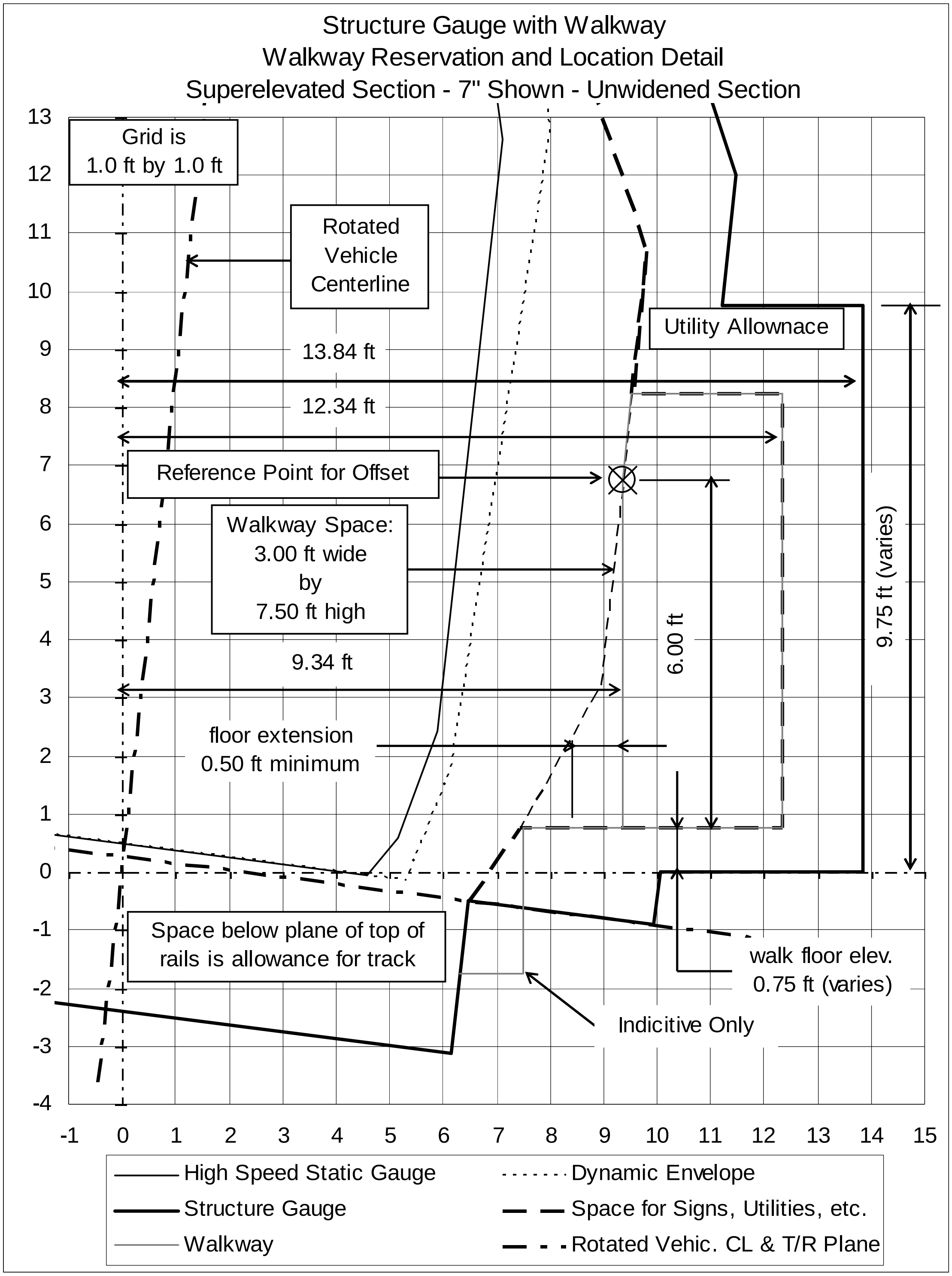


Figure 3.5.2: Walkway Detail, Track with Superelevation



3.5.2 Standard Structure Gauge Outlines

The following sections show standard Structure Gauges for High-Speed Equipment. The first Structure Gauge Outline, Figures 3.5.3, illustrates the section without provision of walkway space to show shapes and dimensions of the portions of the Structure Gauge not affected by the presence of the walkway. Figures 3.5.2 illustrates the walkway and show only those dimensions relevant to the walkway.

The dashed line above the top of the vehicle in the space labeled as “Space for Overhead Contact System” is indicative only. See TM 3.2.3 - Pantograph Clearance Envelope, and TM 3.2.1 - OCS Requirements for definitive space requirements in this zone.

Figure 3.5.3: High-Speed Only Structure Gauge – Without Walkway

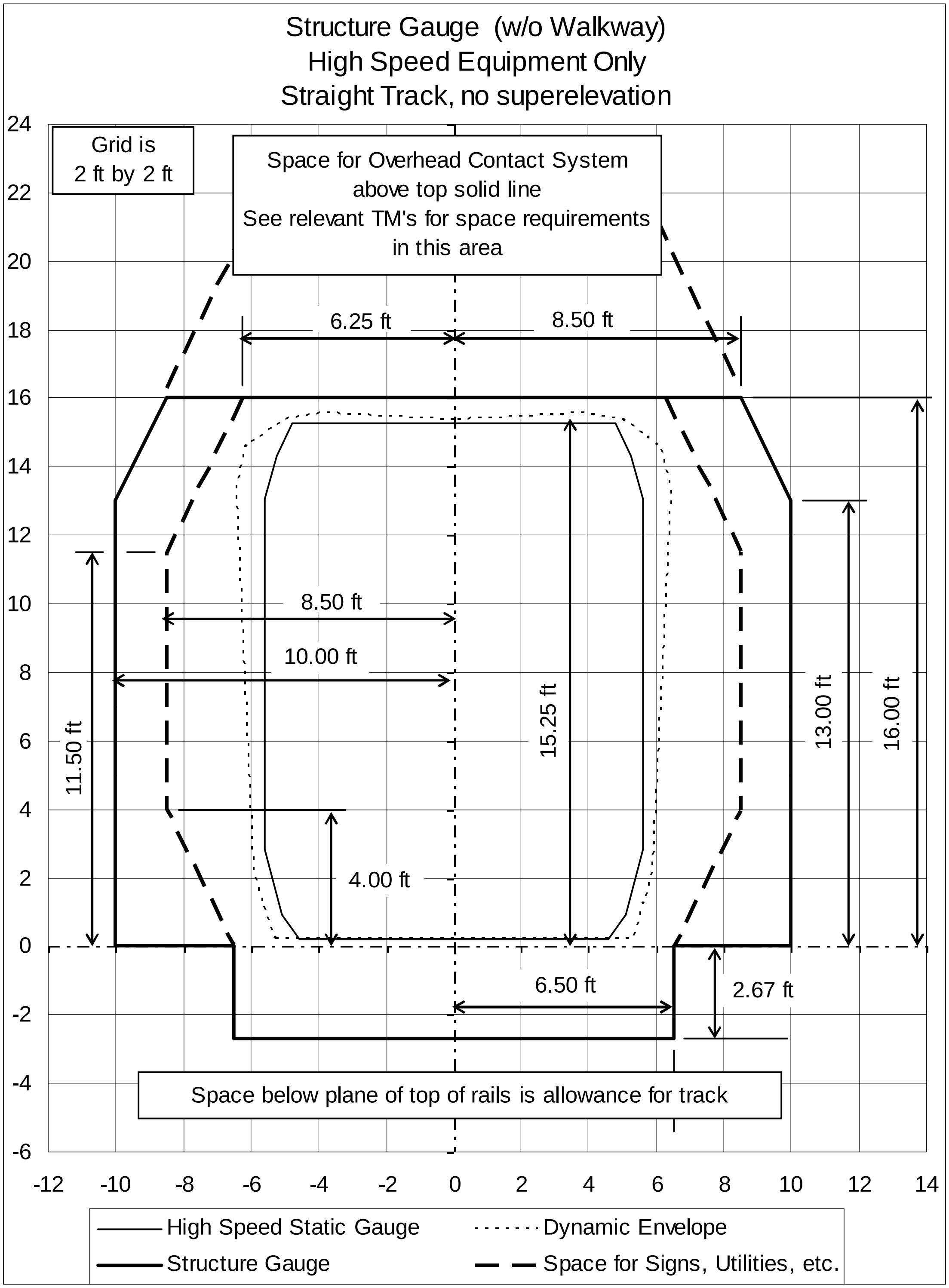
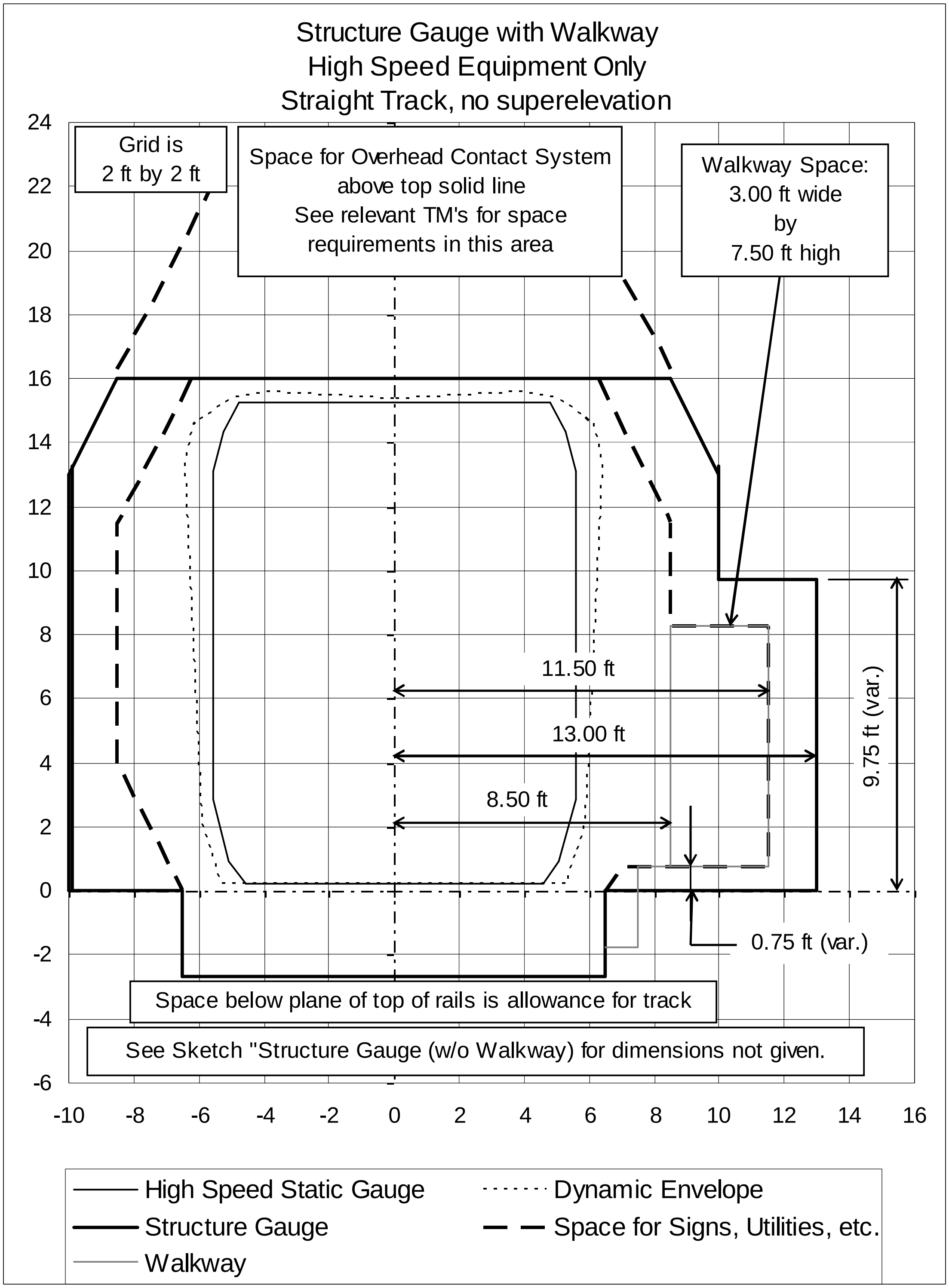
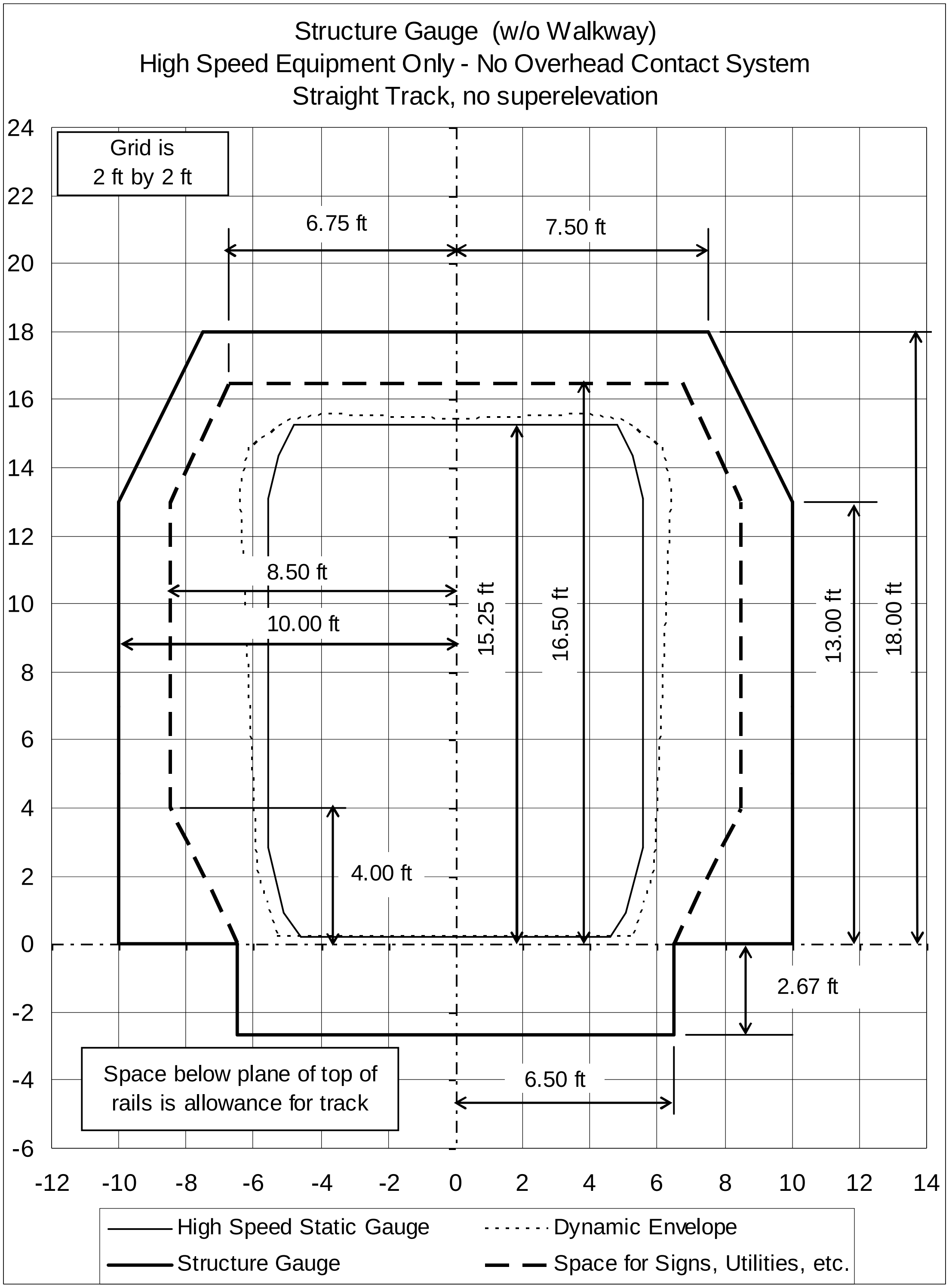


Figure 3.5.4: High-Speed Only Structure Gauge – With Walkway



Certain tracks in yard and shop areas may not have overhead electrification. For these tracks a Structure Gauge no smaller than Figure 3.5.5 shall be applied. This Structure Gauge shall be widened the same as other High-Speed Rail Only Structure Gauges, and shall be rotated in a similar manner in the unlikely event that such a track has any superelevation applied.

Figure 3.5.5: High-Speed Rail Only Structure Gauge – Non-Powered Track – Without Walkway



3.5.3 Curvature and Superelevation effects – High-Speed Structure Gauge Outlines

3.5.3.1 WIDENING OF STRUCTURE GAUGE FOR EFFECTS OF RADIUS OF CURVE

Widening of Structure Gauge shall consider lateral clearance issues with any equipment.

Desirable and Minimum Widening: See paragraph 3.1.6, particularly sub-paragraph 3.1.6.3 for development of the following formula. The widening formula is:

EO (in feet) = MO (in feet) = 550 / R (in feet).

Expressing the offset requirement in the traditional AREMA format of inches per degree of curve:

EO and MO = $1^1/_8$" x Dc

In order to eliminate the need to increase the section width on all curves, the Structure Gauge widening requirement shall be added to a dimension that is 0.25 feet less than the standard offset.

Table 3.5.1: Additional Width from centerline on Curves – Desirable/Minimum for All Tracks

Curve Radius (feet)	Structure Gauge (feet)	Utility Allowance (feet)	Curve Radius (feet)	Structure Gauge (feet)	Utility Allowance (feet)
2200 plus	10.00	8.50	1300	10.17	8.67
2100	10.01	8.51	1200	10.21	8.71
2000	10.03	8.53	1100	10.25	8.75
1900	10.04	8.54	1000	10.30	8.80
1800	10.06	8.56	900	10.36	8.86
1700	10.07	8.57	800	10.44	8.94
1600	10.09	8.59	700	10.54	9.04
1500	10.12	8.62	600	10.67	9.17
1400	10.14	8.64	500	10.85	9.35

Exceptional Widening Main Tracks, Minimum Widening Yard Tracks: Where constrained, the widening shall be based on the potential EO and MO values for the proposed equipment. See paragraph 3.1.6, particularly sub-paragraph 3.1.6.2 for development of the following formula. For High-Speed Equipment the widening formula is:

EO (in feet) = MO (in feet) = 500 / R (in feet).

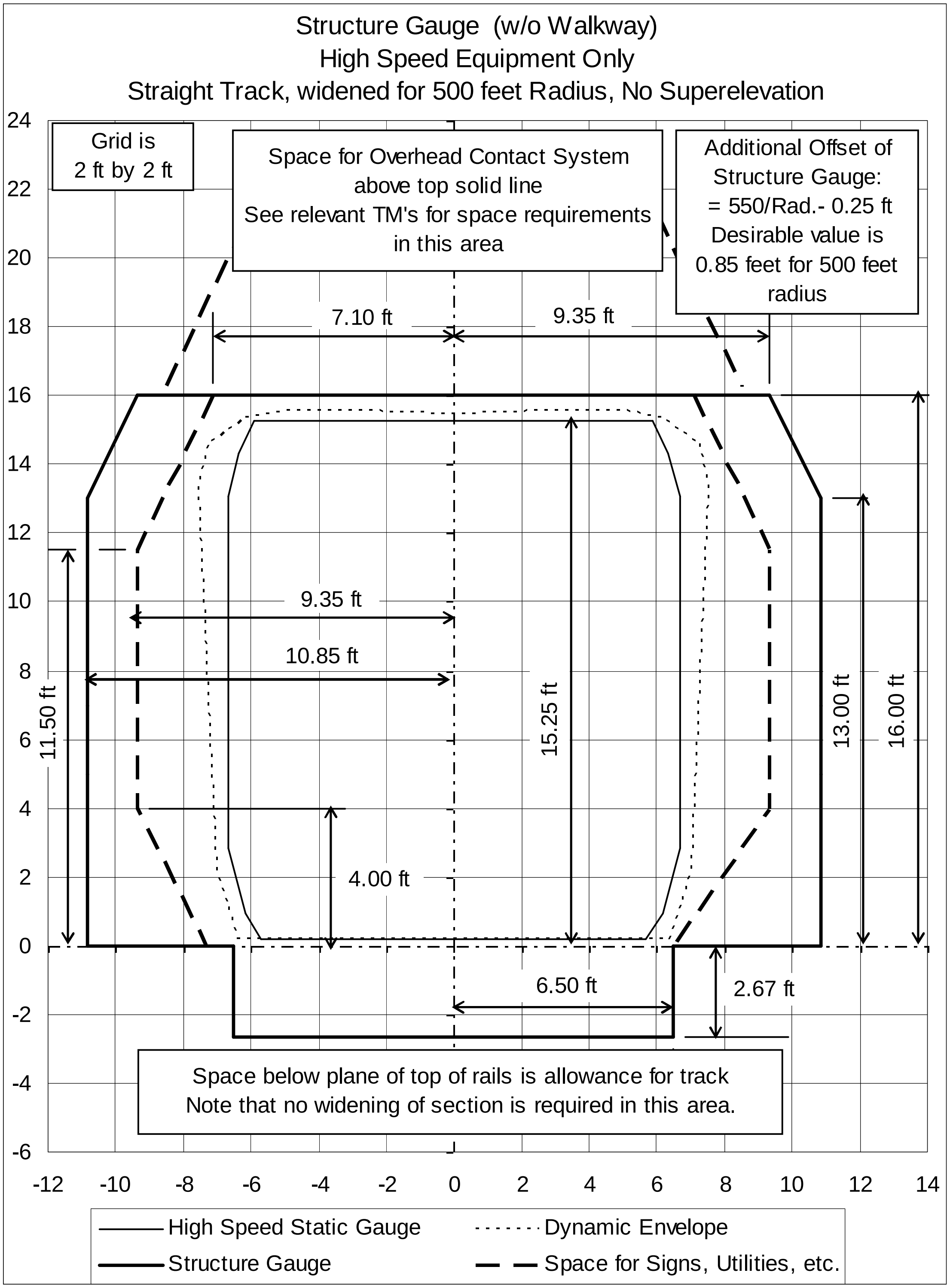
In order to eliminate the need to increase track centers on all curves, the widening requirement shall be added to a dimension that is less than the standard offset.

Table 3.5.2: Exceptional Additional Width from Centerline on Curves – High-Speed Tracks

Curve Radius (feet)	Structure Gauge (feet)	Utility Allowance (feet)	Curve Radius (feet)	Structure Gauge (feet)	Utility Allowance (feet)
2000	10.00	8.50	1200	10.17	8.67
1900	10.01	8.51	1100	10.20	8.70
1800	10.03	8.53	1000	10.25	8.75
1700	10.04	8.54	900	10.31	8.81
1600	10.06	8.56	800	10.38	8.88
1500	10.08	8.58	700	10.46	8.96
1400	10.11	8.61	600	10.58	9.08
1300	10.13	8.63	500	10.75	9.25
2000	10.00	8.50	1200	10.17	8.67
1900	10.01	8.51	1100	10.20	8.70

Location of Placement of Transition to Increased Width in Structure Gauge: The usual object is to ensure sufficient space, not a precise need for additional space. Sufficient offset can be achieved by beginning the transition from the unwidened section 75 feet into the straight track beyond the beginning of the spiral, or of the curve if there is no spiral and achieving the full needed additional offset not less than 25 feet before the beginning of the full arc.

Figure 3.5.6: Example of Widened Structure Gauge – Radius 500 feet



3.5.3.2 ROTATION OF STRUCTURE GAUGE SECTION FOR EFFECTS OF SUPERELEVATION

Point of Rotation: The point of rotation of the section is defined as the gauge corner of the inside rail of the curve. Therefore, the point of rotation is at the profile elevation and offset 2.354 feet from the track centerline toward the inside of the curve. The cross section shall be widened for the effects of curvature and then the widened sections rotated about the point of rotation of the track for superelevation.

Walkways: If the walkway is on the outside of superelevated curves, the offset of the walkway will be the same as on straight track except along small radius curves that require widening of the clearance section. If the walkway is on the inside of the superelevated curve, the track side of the walkway will be located based on the position of the utility allowance at a point not lower than 6.00 feet above the walkway surface or top of rail, whichever is higher.

Widening of Section: If the curve radius is small, widening of the section as described under 3.5.3.2 Widening of Structure Gauge for Effects of Radius of Curve and as shown in Tables 3.5.1 or Table 3.5.2 as applicable shall be done before the section is rotated. The rotated sections shown in Figures 3.5.7, 3.5.8, 3.5.9, and 3.5.10 show the location of points A, B, B' C, D, and E that may define offset requirement to various facilities located close to the tracks.

OCS Considerations: In order to keep the allowance for the OCS as low as practical, the top line shall remain level on the outside of the curve beyond a point that is offset 4.00 feet from the centerline of the top of the section and perpendicular to that line.

Tabulation: Table 3.5.3 provides dimensions for these locations for the superelevated condition at varying superelevations from zero to 7 inches in full inch increments. The X values are the lateral distance from vertical centerline, without sign, and the Y values are the elevation above top of low rail of the curve. The walkway height may vary from that given in this example.

Table 3.5.3: Points around Unwidened and Rotated High-Speed Only Structure Gauge

Ea (inch)	A		B		B'		C		D		E	
	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
0	10.000	0.000	8.500	16.000	4.000	16.000	0.000	16.000	8.500	16.000	13.000	9.750
1	9.998	0.208	8.269	16.104	3.730	16.104	0.269	16.038	8.768	15.894	13.114	9.750
2	9.993	0.415	8.038	16.204	3.458	16.204	0.539	16.070	9.034	15.784	13.231	9.750
3	9.984	0.623	7.808	16.300	3.185	16.300	0.810	16.098	9.299	15.670	13.348	9.750
4	9.972	0.831	7.578	16.391	2.910	16.391	1.081	16.122	9.562	15.551	13.468	9.750
5	9.957	1.038	7.348	16.478	2.633	16.478	1.353	16.141	9.823	15.427	13.591	9.750
6	9.937	1.246	7.118	16.559	2.354	16.559	1.626	16.156	10.083	15.298	13.716	9.750
7	9.914	1.453	6.890	16.637	2.073	16.637	1.898	16.166	10.340	15.166	13.843	9.750

No table is given for the combination of widened and superelevated sections. For the combined condition the values can be calculated using the various formulae given in this Technical Memo, as the offset of the various points will vary with radius.

Sample Sections of Superelevated Structure Gauges: The following sections show the standard Structure Gauge for High-Speed Tracks as affected by superelevation and widening. Only the extreme cases of superelevation and the combination of superelevation and widening are shown. For the effects of other values of superelevation and widening, see the appropriate tables, or calculate values using the information given above. The first set of Structure Gauge Outlines, Figures 3.5.7 and 3.5.8 illustrates these sections without provision of walkway space to show shapes and dimensions of the portions of the Structure Gauge not affected by the presence of the walkway. Figures 3.5.9 and 3.5.10 illustrate the walkway and show only those dimensions relevant to the walkway.

Figure 3.5.7: High-Speed Only Structure Gauge – Without Walkway Rotated for 7" Superelevation

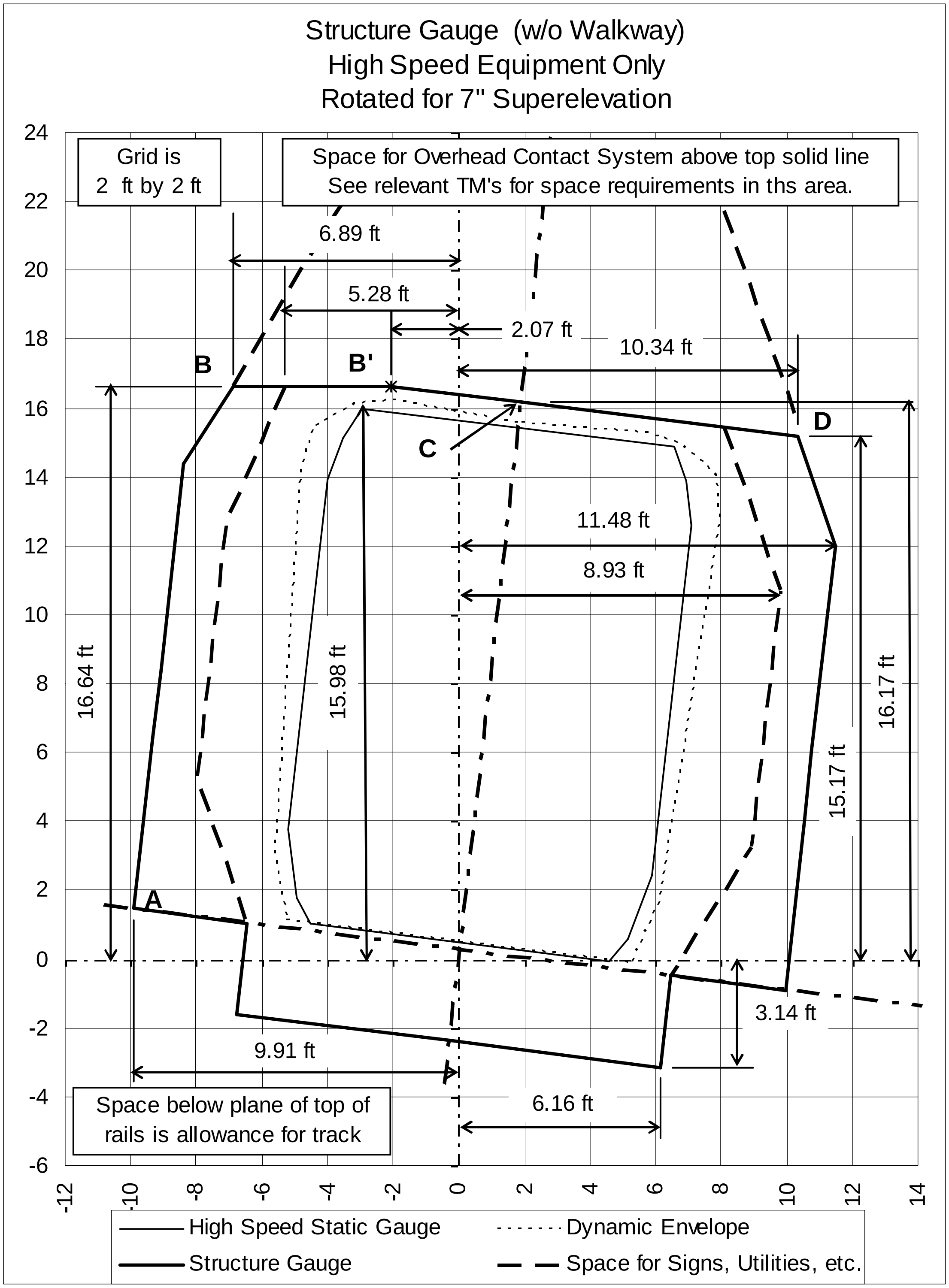


Figure 3.5.8: High-Speed only Structure Gauge – Without Walkway Widened for 500' Radius and Rotated for 7" Superelevation

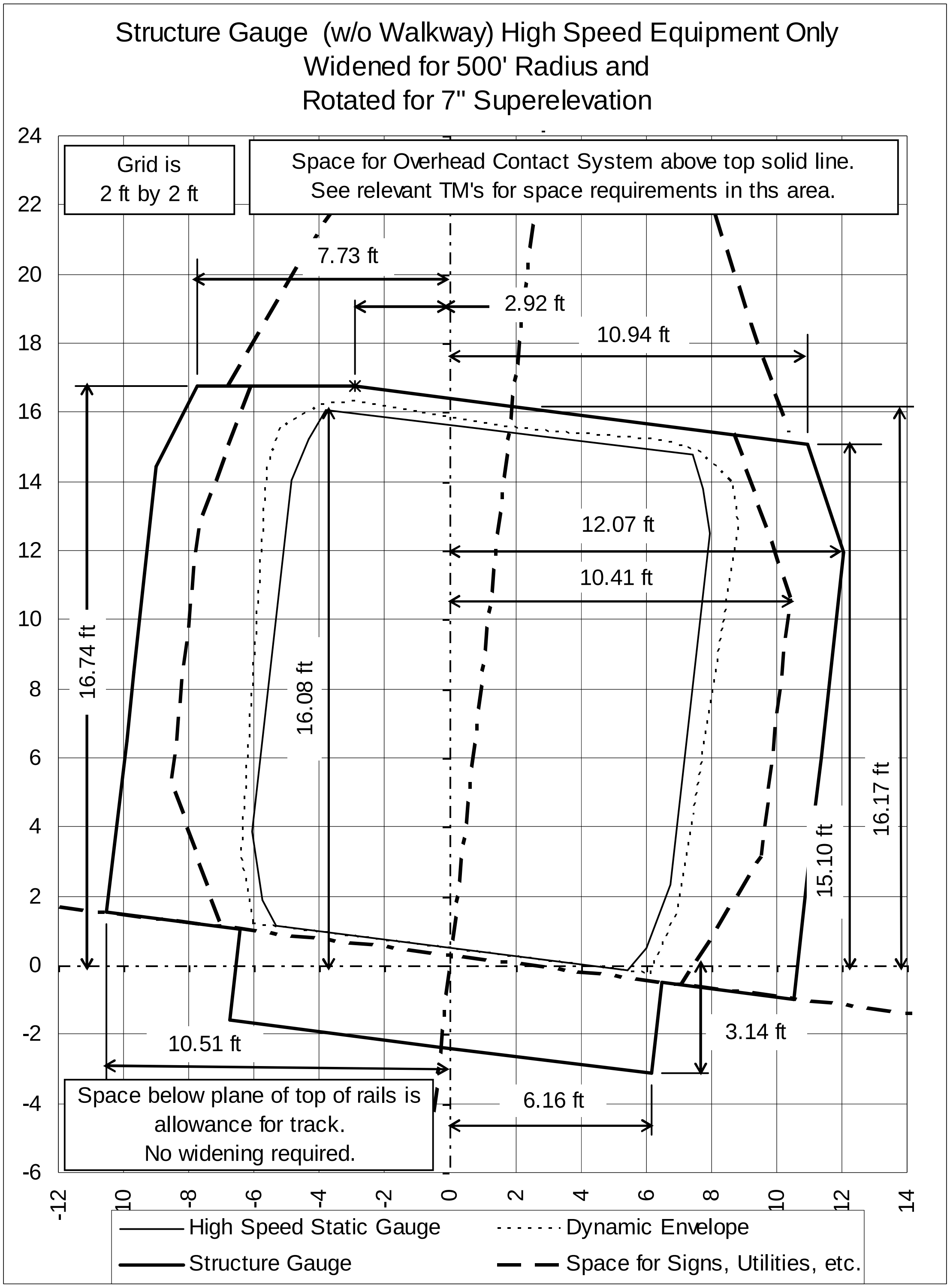
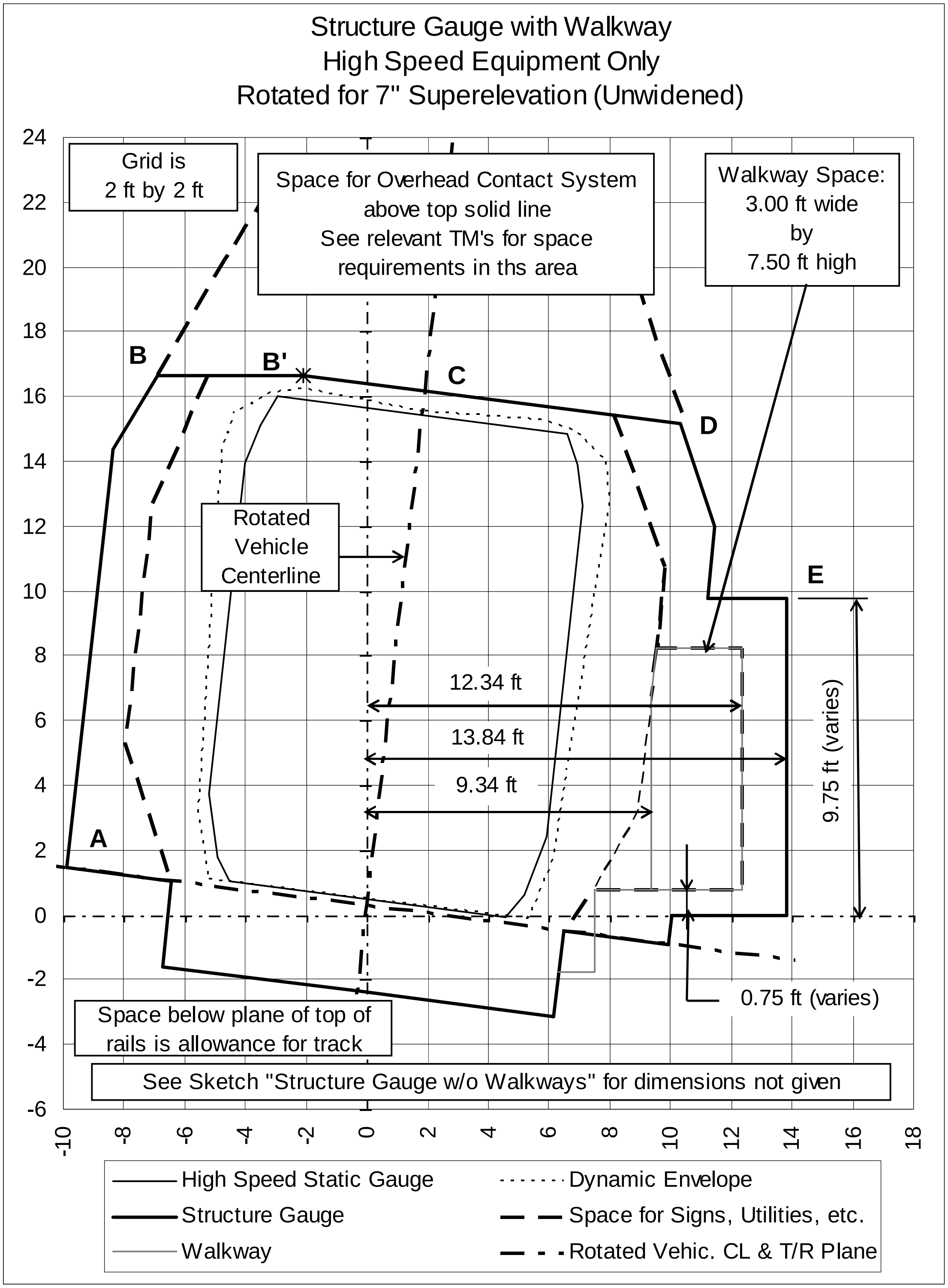


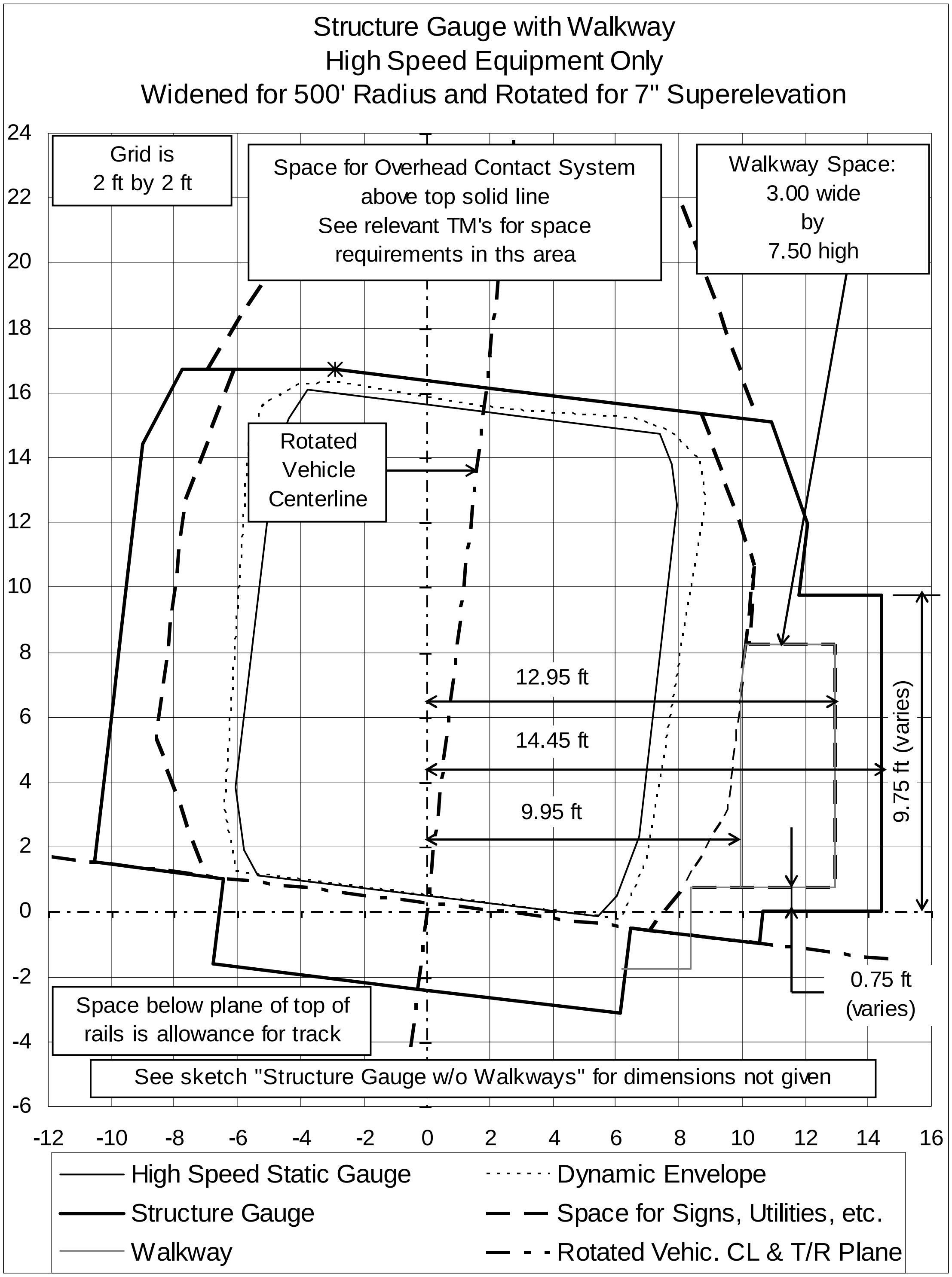
Figure 3.5.9: High-Speed Only Structure Gauge – With Walkway Rotated for 7” Superelevation



Notes:

1. If walkway is on the high side of the curve, offset from track is unaffected by superelevation.
2. Minimum offset of track side of walkway is Utility Allowance offset at a point 6.00 feet above bottom of walkway.

Figure 3.5.10: High-Speed Only Structure Gauge – With Walkway Widened for 500 feet Radius and Rotated for 7” Superelevation



Notes:

1. If walkway is on the high side of the curve, offset from track is unaffected by superelevation but is affected by widening of section due to the radius effect.
2. Minimum offset of track side of walkway is Utility Allowance offset at a point 6.00 feet above bottom of walkway. .

3.6 TRACK CENTERS

Track center spacing is related to but not necessarily controlled by the Structure Gauge dimensions.

3.6.1 CPUC Minimums

CPUC GO 26D Section 5 defines minimum clearances between parallel tracks:

Section 5-Clearance Between Parallel Tracks

5.1 The minimum distance between the center lines of parallel standard gauge tracks shall be fourteen (14) feet except as hereinafter provided.

5.2 The center line of any standard gauge track, except a main track or a passing track, parallel and adjacent to a main track or a passing track, shall be at least fifteen (15) feet from the center line of such main track or passing track; provided, however, that where a passing track is adjacent to and at least fifteen (15) feet distant from the main track, any other track may be constructed adjacent to such passing track with clearance prescribed in subsection 5.1 of this order.

5.3 The center line of any standard gauge ladder track, constructed parallel to any other adjacent track, shall have a clearance of not less than twenty (20) feet from the center line of such other track.

5.4 The minimum distance between the center lines of parallel team, house and industry tracks shall be thirteen (13) feet.

5.5 Main, siding and yard tracks constructed prior to the effective date of this order with distance of not less than thirteen (13) feet between track centers may be extended without increasing such distances.

CPUC GO Sub-section 9.2 requires a clear space of 24 inches between tracks. Note that this dimension is less than the 2.50 feet clear space between equipment and an adjacent structure. Based on the Shinkansen body width of 3380 mm (11.09 feet); the minimum allowed track centers would be 13.09 feet. However, track centers would have to be widened on all curves due to the effects of mid car / end car overhangs and superelevation if this value were used.

At any speed, there shall always be provided at minimum sufficient space for a person to be clear of standing vehicles between tracks, regardless of whether or not such space is formally designated as a walkway. Two feet is too narrow for this spacing. No less than 3.00 feet should be provided in all locations. In addition, at higher speeds aerodynamic effects require larger track centers. Therefore, CPUC requirements will not govern the selection of track center spacing.

3.6.2 Other Minimums

Despite the fact that the width of railroad equipment used in this country has remained essentially unchanged for most of the last century, track center spacing requirements have increased from 13.00 feet to 14.00 feet, or more. Currently, most railroad companies require track centers to be 15.00 feet or larger unless constrained by expensive-to-modify exiting conditions. This increase has also been true for transit systems. Examples of standard track centers on transit systems using 10 feet wide cars are WMATA, Washington DC, 14.00 feet and MARTA, Atlanta GA, 14.75 feet. Another reason to use wider than calculated minimum track centers is to avoid the need to increase track centers on every curve.

Since the CHST system must allow for equipment as wide as that on the Shinkansen, the Shinkansen system standard would be the minimum permissible. Their minimum track centers are 4300 mm (14.11 feet). For the Taiwan HSR, the minimum track centers for all tracks, mainline and yards, is 4500 mm (14.76 feet), although centers of 4300 mm were used in one very constricted area where the speed limit was 60 km/h (37 mph). The recently built high speed lines in both South Korea and China use 5000 mm (16.40 feet) track centers even though both use European equipment that is less than three meters (10 feet) wide.

3.6.3 Standard Track Centers – All Tracks

Track centers shall be as follows:

- Main tracks shall be placed at 20.00 feet track centers where space permits.
- Speeds above 125 mph:
  - Desirable: 16.50 feet
  - Minimum: 15.75 feet
  - Exceptional: 15.00 feet – do not use above 175 mph
- Speeds of 125 mph and under:
  - Desirable: 16.50 feet – Use 15.75 feet where 16.50 feet is not practical
  - Minimum: 15.00 feet
  - Exceptional: 14.75 feet – do not use above 90 mph
- Yard and Station and other low speed tracks (under 40 mph:
  - Desirable: 15.00 feet
  - Minimum: 15.00 feet
  - Exceptional: 14.00 feet
- Tracks with Catenary Poles between them:
  - Desirable: 25.00 feet
  - Minimum: 22.00 feet, (standard catenary pole centerline location is 10.67 feet offset from track center)
  - Exceptional: 22.00 feet,

Use of Desirable values will eliminate the need to adjust track centers for radius and superelevation. Use of Minimum values will eliminate the need to adjust track centers under most conditions. The effect of radius and superelevation shall be analyzed for all curves with track at less than Minimum track centers.

3.6.4 Superelevation Effects

Widening of track centers on curves due to the effects of superelevation is not required for curves set at Desirable Track Centers. In the case of curves under 3,000 foot radius and the inside track having less superelevation than the outside track, additional space is required between tracks with track centers set to Minimum and Exceptional track center distances. This widening shall be 2.0 times the difference in superelevation where only high speed equipment is operated, 2.2 times the difference in superelevation where other passenger equipment is also operated, and 4.0 times the difference in superelevation where freight will be operated on the track having the greater superelevation.

3.6.5 Curvature Effects

The required increase is expressed by a formula in the form of:

Increase in Track Centers = Constant / Radius

The Constant is specific to the truck center and body length dimensions of the vehicle and the units of measurement. The constant in the formula is the sum of the constants in the end car offset and mid car offset formulae. The increase may be set to a rounded number. The value shall be rounded up. It shall not be rounded down.

In the following formulae, “main tracks” includes main tracks, station tracks, yard lead tracks or other tracks of similar purpose and “yard tracks” includes low speed tracks in yards and other lightly used low speed tracks.

Desirable Track Centers Increase due to Radius: No widening is required for tracks set at 16.50 feet track centers.. For tracks set at less than 16.50 feet track centers, the track centers defined by the widening formula under Minimum Track Centers Increase shall be applied. For yard tracks, the desirable track centers shall be not less than the Minimum Track Centers for Main Tracks.

Minimum Track Centers Increase due to Radius: For tracks spaced at less than 16.50 feet, the allowed minimum track centers shall be determined by adding the value determined by the following formula to 14.25 feet.

Increase in Track Centers (in feet) = 1,100 / R (in feet).

Thus, on curves, the Minimum Track Centers for main tracks and the Desirable Track Centers for yard tracks shall be:

The greater of either: 14.25 feet + 1,100 / R (in feet) or 15.00 feet

Exceptional Track Centers Increase due to Radius: The Exceptional minimum track centers shall be determined by adding the value determined by the following formula to 14.25 feet for main tracks or 13.75 feet for yard tracks.

Increase in Track Centers (in feet) = 1,000 / R (in feet).

Thus, the Exceptional Track Centers on curves shall be:

For main tracks, the greater of either: 14.25 feet + 1,000 / R (in feet) or 15.00 feet

For yard tracks, the greater of either: 13.75 feet + 1,000 / R (in feet) or 14.00 feet

Figure 3.6.1: Track Centers Required on Small Radius Curves

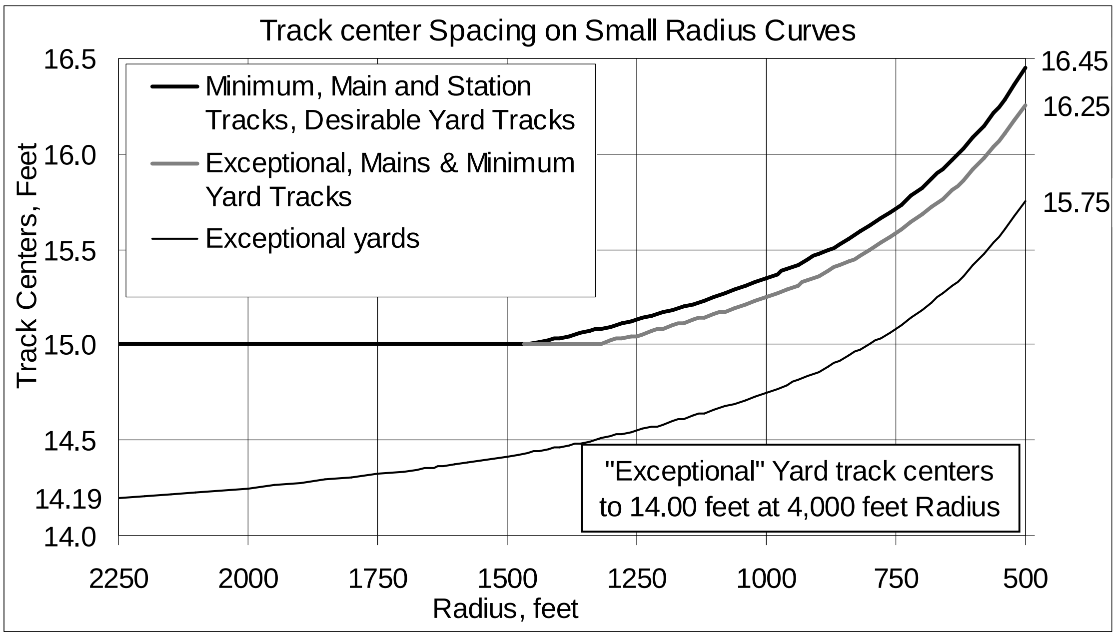


Table 3.6.1: Sample Tabulation of Track Centers Required on Small Radius Curves

Radius feet	Minimum, Main feet	Exceptional Main/Yard Minimum feet	Exceptional Yard feet	Radius feet	Minimum, Main feet	Exceptional Main/Yard Minimum feet	Exceptional Yard feet
4000+	15.00	15.00	14.00	1100	15.25	15.16	14.66
3000	15.00	15.00	14.08	1000	15.35	15.25	14.75
2500	15.00	15.00	14.15	**950**	**15.41**	**15.30**	**14.80**
2000	15.00	15.00	14.25	900	15.47	15.36	14.86
1800	15.00	15.00	14.31	800	15.63	15.50	**15.00**
1600	15.00	15.00	14.38	700	15.82	15.68	15.18
1470	15.00	15.00	14.43	650	15.94	15.79	15.29
1400	15.04	15.00	14.46	**620**	**16.02**	**15.86**	**15.36**
1340	15.07	15.00	14.50	600	16.08	15.92	15.42
1300	15.10	15.02	14.52	550	16.25	16.07	15.57
1200	15.17	15.08	14.58	500	16.45	16.25	15.75
1200	15.17	15.08	14.58	500	16.45	16.25	15.75

3.6.6 Transitioning at Changes in Track Centers

Due to Radius Effects on Parallel/Concentric Tracks: The preferred method of adjusting track centers is to do it over the length of the spiral transitions at the ends of the curves. This should be done by calculating a spiral of appropriate length for the speed and superelevation effects for the outside track on the curve. The inside spiral will be set longer so that the tangent to offset arc of the inside spiral is larger than that of the outside spiral by the amount of the chosen increase in track centers.

Due to Changes in the Set Track Centers: Changes should not be done by installing a reverse curve in one or both tracks. The Desirable and Minimum method is to make the change over a length of curve or over one of the spirals in a curve. Only under exceptional conditions may reverse curves in otherwise straight track be used to change track centers.

3.7 PASSENGER PLATFORM OFFSETS AND ELEVATIONS

Station Platform offsets and elevations will be specific to the equipment operated. Since the type of equipment is unknown at this time, the platform edge location specific to the CHSTP cannot be finalized in this Technical Memo. The relationship between car floor and passenger platform is governed by the requirements in 49CFR Part 38, Americans with Disabilities Act (ADA) Accessibility Specifications for Transportation Vehicles, paragraph 38.175, which in part states as follows:

(a) All cars for high-speed rail systems, including but not limited to those using “maglev” or high speed steel-wheel-on-steel rail technology, and monorail systems operating primarily on dedicated rail (i.e., not used by freight trains) or guideway, in which stations are constructed in accordance with part 37, subpart C of this title, shall be designed for high-platform, level boarding . . . The design of cars shall be coordinated with the boarding platform design such that the horizontal gap between a car door at rest and the platform shall be no greater than 3 inches and the height of the car floor shall be within plus or minus 5/8 inch of the platform height under all normal passenger load conditions. Vertical alignment may be accomplished by car air suspension or other suitable means of meeting the requirement. All doorways shall have, when the door is open, at least 2 foot-candles of illumination measured on the door threshold.

(Part 37, Subpart C provides a number of requirements that are irrelevant to the issue of clearances.)

Design Values for offset and elevation shall be set to be sufficiently less than the FRA requirement to ensure that construction and maintenance tolerances and equipment movements during normal operations do not result in a non-compliant gap.

4.0 SUMMARY AND RECOMMENDATIONS

The recommended Structure Gauges and Track Center spacings are summarized in Section 6.0

5.0 SOURCE INFORMATION AND REFERENCES

1. Manual for Railway Engineering of the American Railway Engineering and Maintenance of Way Association (AREMA Manual)
2. Federal Railroad Administration Code of Federal Regulations (CFR)
   - 49CFR Part 213, Track Safety Standards, generally and also in particular Subpart G—Train Operations at Track Classes 6 and Higher
   - 49CFR Part 214, Railroad Workplace Safety
3. Other US Code Requirements
   - 29CFR Part 1910, Occupational Health and Safety Administration (OHSA) Occupational Safety and Health Standards
   - 36CFR Chapter XI, Part 1191 Americans with Disabilities Act (ADA) Accessibility Guidelines for Buildings and Facilities
   - 49CFR Part 38, Americans With Disabilities Act
4. APTA RP-C&S-003-98 (Edited 3-22-04) Recommended Practice for Developing a Clearance Diagram for Passenger Equipment
5. California Department of Transportation, Manuals and Standards
6. California Public Utilities Commission General Order 26D, 118
7. Rail Safety and Standards Board (UK) Guidance on Gauging (for UIC Gauges)
8. DS 804, Regulation for Railway Bridges and other Engineering Works (Germany)
9. National Fire Protection Association, NFPA 130: Standard for Fixed Guideway Transit and Passenger Rail Systems
10. European Union’s Technical Specifications for Interoperability, latest version of that originally published as Directive 96/48/EC—Interoperability of the Trans-European High Speed Rail System
    - ‘Infrastructure’ Sub-System (dated March 19, 2008)
    - ‘Rolling Stock’ Sub-system (dated March 26, 2008)
11. European Union’s Technical Specifications for Interoperability, latest version of that originally published as Directive 2001/16/EC—Interoperability of the Conventional Rail System
    - ‘Rolling Stock—Freight Wagons’ Sub-system (dated December 8, 2006)

6.0 DESIGN MANUAL CRITERIA

6.1 GENERAL – STRUCTURE GAUGES AND TRACK CENTERS

Track center spacing is related to but only partially controlled by the Structure Gauge dimensions. The distance between high-speed train track centers considers aerodynamics, design speed, and ease of maintenance. Where aerodynamic analysis demonstrates that larger values are required, the larger values shall become the minimum distances between track centers for the high-speed rolling stock and design speed under consideration. The distance between track centers may be increased for passenger comfort or maintenance requirements.

Although the width of railroad equipment used in this country has remained essentially unchanged for most of the last century, both required spacing around tracks and track center spacing requirements have increased several times during this time frame. Commonly used minimum track centers have increased from 13.00 feet to 14.00 feet, 15.00 feet, and where unconstrained by right of way, to 20.00 feet or more. The minimum space from center of track to a wall or fixed object has increased from under 8.00 feet to 8.00 feet then to 8.50 feet, and now 9.00 feet, and for many systems more. These increases have been justified on the basis of ease of maintenance, reduced complexity in crossovers, and improved safety.

6.2 TRACK CENTERS

The distance between track centers shall remain constant to the greatest extent practical.

6.2.1 Track Centers – Straight Tracks

Where space permits and the cost of doing so is not excessive, the track centers for main tracks shall be set at 20.00 feet. Where placing track at twenty feet track centers is not practical or is excessively costly, the following track center dimensions shall be used.

- Speeds above 125 mph:
  - Desirable: 16.50 feet
  - Minimum: 15.75 feet
  - Exceptional: 15.00 feet – do not use above 175 mph
- Speeds of 125 mph and under:
  - Desirable: 16.50 feet – Use 15.75 feet where 16.50 feet is not practical
  - Minimum: 15.00 feet
  - Exceptional: 14.75 feet – do not use above 90 mph
- Yard, Yard Lead and Station and other tracks with speeds under 50 mph:
  - Desirable: Yard Lead and Station Tracks: 16.50 feet, Yard Tracks: 15.00 feet
  - Minimum: 15.00 feet
  - Exceptional: 14.00 feet
- Tracks with Catenary Poles between them:
  - Desirable: 25.00 feet
  - Minimum: 22.00 feet, without walkway
  - Exceptional: 22.00 feet, without walkway

6.2.2 Effects of Small Radius on Track Centers

The required increase is expressed by a formula in the form of:

- Increase in Track Centers = Constant / Radius

The Constant is specific to the truck center and body length dimensions of the vehicle and the units of measurement. The increase may be set to a rounded number. The value shall be rounded up. It shall not be rounded down.

Desirable Track Centers Increase due to Radius: No widening is required for tracks set 16.50 feet track centers.. For tracks set at less than 16.50 feet track centers, the track centers defined by the widening formula under Minimum Track Centers Increase shall be applied.

Minimum Track Centers Increase due to Radius: For tracks spaced at less than 16.50 feet, the allowed minimum track centers shall be determined by adding the value determined by the following formula to 14.25 feet.

Track Center Increase (in feet) = 1,100 / R (in feet).

Exceptional Track Centers Increase due to Radius: The Exceptional track centers shall be determined by adding the value determined by the following formula to 14.25 feet for main tracks or 13.75 feet for yard tracks.

Track Center Increase (in feet) = 1,000 / R (in feet).

Figure 6.2.1: Track Centers Required on Small Radius Curves -US Units

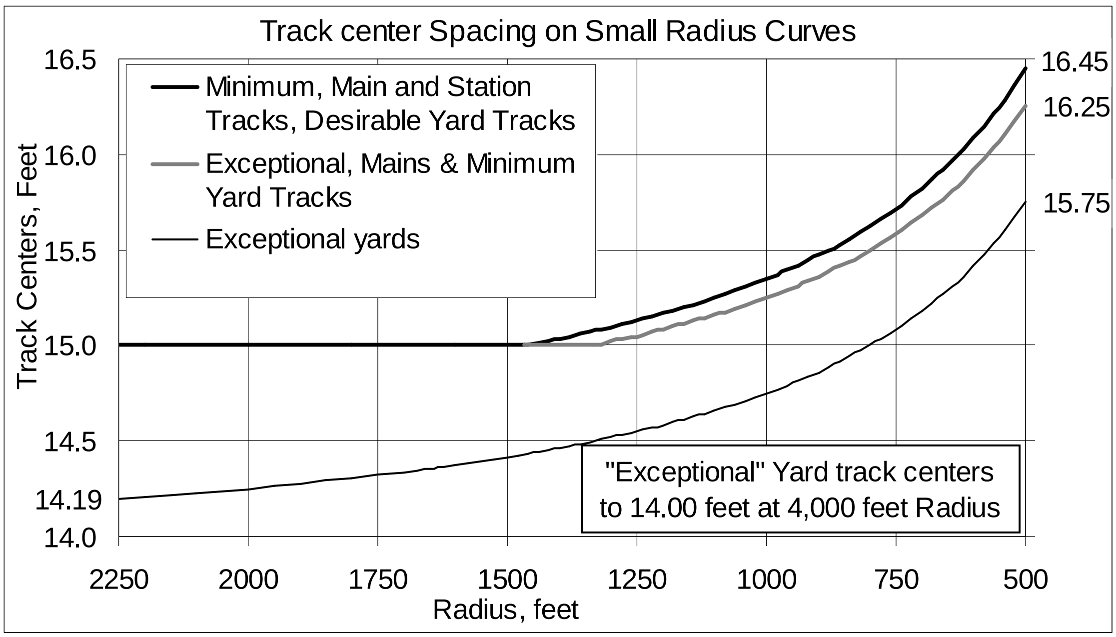


Table 6.2.1: Sample Tabulation of Track Centers Required on Small Radius Curves

Radius feet	Minimum, Main feet	Exceptional Main/Yard Minimum feet	Exceptional Yard feet	Radius feet	Minimum, Main feet	Exceptional Main/Yard Minimum feet	Exceptional Yard feet
4000 plus	15.00	15.00	14.00	1100	15.25	15.16	14.66
3000	15.00	15.00	14.08	1000	15.35	15.25	14.75
2500	15.00	15.00	14.15	**950**	**15.41**	**15.30**	**14.80**
2000	15.00	15.00	14.25	900	15.47	15.36	14.86
1800	15.00	15.00	14.31	800	15.63	15.50	**15.00**
1600	15.00	15.00	14.38	700	15.82	15.68	15.18
1470	15.00	15.00	14.43	650	15.94	15.79	15.29
1400	15.04	15.00	14.46	**620**	**16.02**	**15.86**	**15.36**
1340	15.07	15.00	14.50	600	16.08	15.92	15.42
1300	15.10	15.02	14.52	550	16.25	16.07	15.57
1200	15.17	15.08	14.58	500	16.45	16.25	15.75
1200	15.17	15.08	14.58	500	16.45	16.25	15.75

6.2.3 Effects of Superelevation on Track Centers

Widening of track centers on curves due to the effects of superelevation is not required for curves on Desirable Track Centers. In the case of curves under 3,000 feet radius and the inside track having less superelevation than the outside track, additional space is required between tracks with track centers set to Minimum and Exceptional track center distances. This widening shall be 2.0 times the difference in superelevation.

6.2.4 Other Considerations Affecting Track Centers

Where walkways, catenary poles, signal equipment, or other facilities are between tracks, the space between track centers shall be increased sufficiently to provide required clearances to such features.

6.2.5 Transitioning at Changes in Track Centers

Due to Radius Effects on Parallel/Concentric Tracks: The preferred method of adjusting track centers is to do it over the length of the spiral transitions at the ends of the curves. This should be done by calculating a spiral of appropriate length for the speed and superelevation effects for the outside track on the curve. The inside spiral will be set longer so that the tangent to offset arc of the inside spiral is larger than that of the outside spiral by the amount of the chosen increase in track centers.

Due to Changes in the Set Track Centers: Changes shall not be done by installing a reverse curve in one or both tracks. The preferred method is to make the change over a length of curve or over one of the spirals in a curve.

6.3 STRUCTURE GAUGES

6.3.1 Definition

Structure Gauges define the closest proximity allowed for any facility near the track. Structure gauges represent the minimum distances to be provided adjacent to the tracks where other considerations do not require a larger distance. Walkways are not shown in the first Structure Gauge sections; however, walkways shall be required on at least one side of all tracks.

6.3.2 Limitations of Applicability

The Structure Gauges are not typical sections, but indicate the minimums to be used in development of typical sections. Neither are the Structure Gauges Clearance Diagrams for typical cross sections in bridges and tunnels. Nor do Structure Gauges include any consideration for aerodynamic or other effects that may require a larger clear space around the tracks.

The Structure Gauge is of sufficient height to clear the various high speed trainsets under consideration, the European Union's Technical Specification for Interoperability GC Kinematic Outline, and no more. Therefore, it is highly desirable that overhead features be located so as to not cause vertical increases in clearance in the future to be exorbitantly expensive.

Allowances for catenary and other overhead power related facilities that are above the top of the vehicle are not part of this section, but may be found elsewhere.

6.3.3 Explanation of Figures

The Structure Gauge figures define three limits:

- The heavy solid line surrounding the vehicle outline defines the closest permitted location of major features such as retaining walls, through truss bridge elements, tunnel sides, etc. For tracks that will have an Overhead Catenary System (OCS), the top solid line of these sections indicates the lower limit of the allowance for the OCS.
- The heavy dashed line inside the solid line defines the closest permitted location of utilities and intermittent features such as:
  - Conduits and cables
  - Fire Water lines
  - Catenary system
  - Signs and Markers
- The heavy dashed line above the top solid line serves only to indicate that there is a required allowance for the OCS above these Structure Gauge limits. It is not intended to define the side and top limits of this OCS allowance.
- The heavy grey line indicates the allowance for walkway space

6.3.4 Walkway Requirements

A walkway space shall be provided along at least one side of every track. The heavy grey line on the Structure Gauge Outlines indicates the allowance for walkway space and its closest allowable proximity to the track. Walkways serve two primary purposes:

- Pathways and refuge areas for employees on the trackway for maintenance, inspection, or other duties.
- Passenger evacuation in case of the need to detrain passengers outside stations

Where catenary poles are located adjacent to a track, the track side edge of the walkway may be set at the field side of the catenary pole. Otherwise, the offset to the trackside edge of the walkway shall be beyond the Space for Utilities portion of the structure gauge.

There are a number of regulatory requirements that must be considered in the placement and sizing of walkways. These include but are not necessarily limited to the following:

- CPUC GO 26 D
- CPUC GO 118.
- OSHA Standards (29CFR 1910, paragraph 36)
- The ADA Accessibility Guidelines for Buildings and Facilities.

Considering all these requirements, the walkway envelope should be defined as follows:

- The walkway width should be not less than 3.00 feet and shall be no less than 2.75 feet. This width shall prevail from walkway surface to a point 6.00 feet above the walkway surface. Above that height, the section may taper inward on the track side where the track is superelevated.
- The vertical walkway space shall be no less than 7.50 feet above the walkway surface or top of rail elevation, whichever is higher
- The walking surface shall be no less than 6 inches wider than the walkway envelope so as to be ADA compliant walkway for evacuation purposes. Normally this additional width may be on the side toward the track.

Where speeds are less than 50 mph, the offset to the trackside edge of the walkway envelope may be reduced by 1.00 feet. In the case of walkways in tunnels or adjacent to walls, sufficient additional offset for mounting of pipes and other fixtures shall be added to ensure that these features do not encroach into the walkway allowance.

6.3.5 Walkway Envelopes - Illustrations

The following figures, Figure 6.3.1 and 6.3.2 illustrate the walkway envelope and its relationship to the Structure Gauge for other features for straight and superelevated tracks respectively. See sections 6.3.6 and following for the development and explanation of other features in the Structure Gauge.

Figure 6.3.1: Walkway Detail, Track without Superelevation

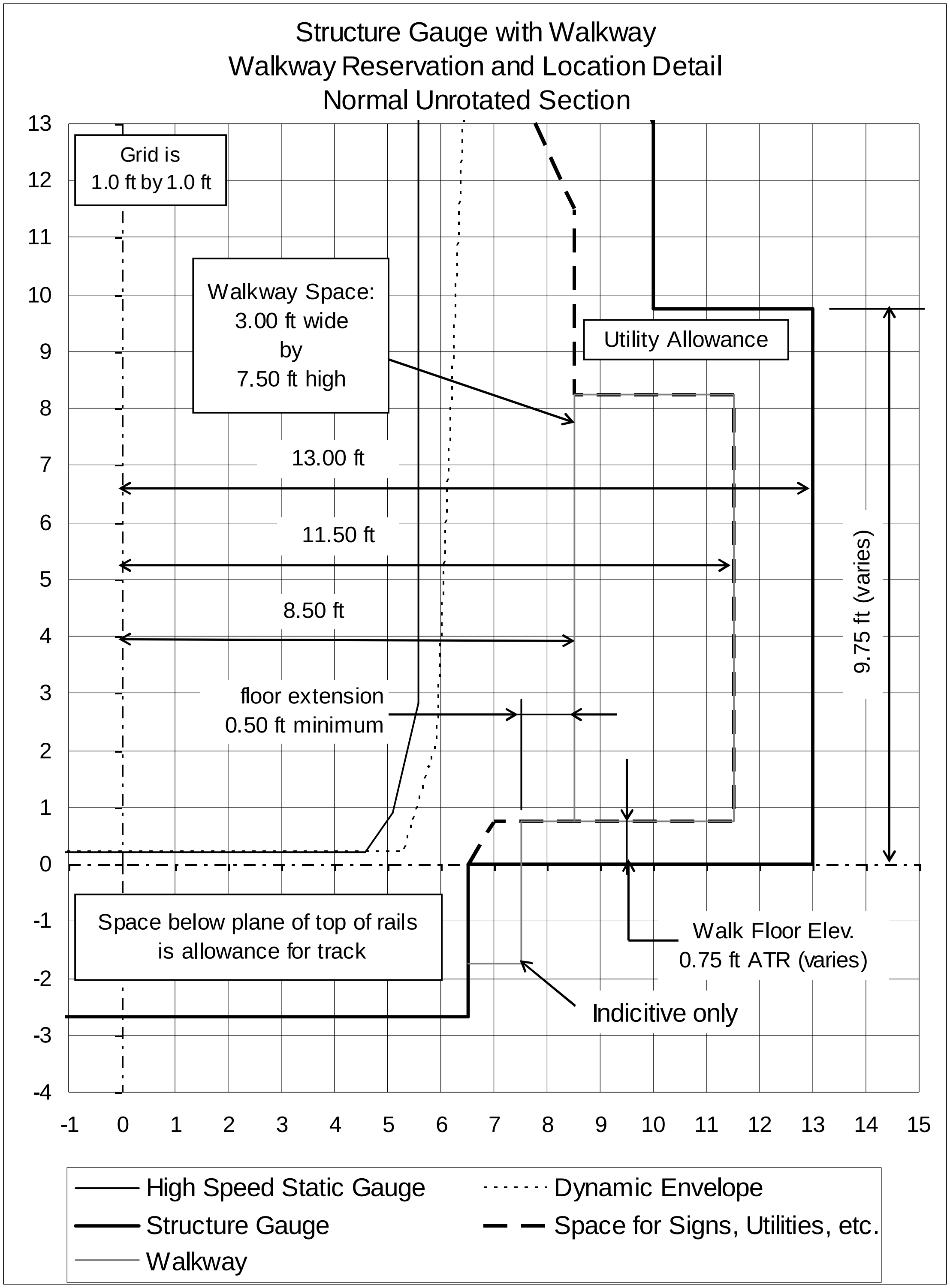
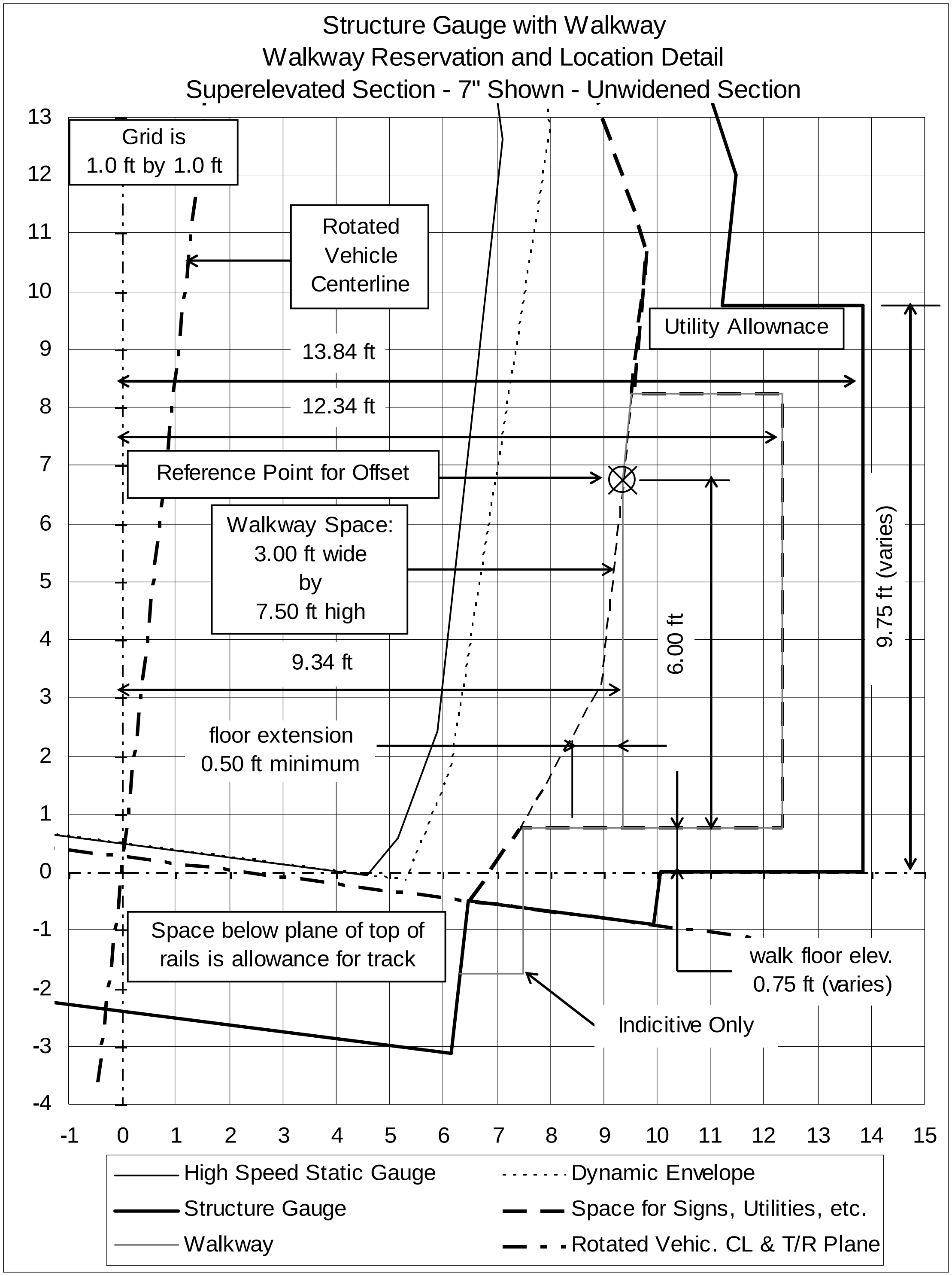


Figure 6.3.2: Walkway Detail, Track with Superelevation



6.3.6 Explanation of Figures – Straight Track Figures

The following structure gauges illustrate the required minimum structure gauges on straight tracks. These sections form the basis for all further structure gauge requirements. These shapes are widened and rotated (about the inside rail) to develop the structure gauge dimensions necessary for curves.

Figure 6.3.3: High-Speed Only Structure Gauge – Without Walkway

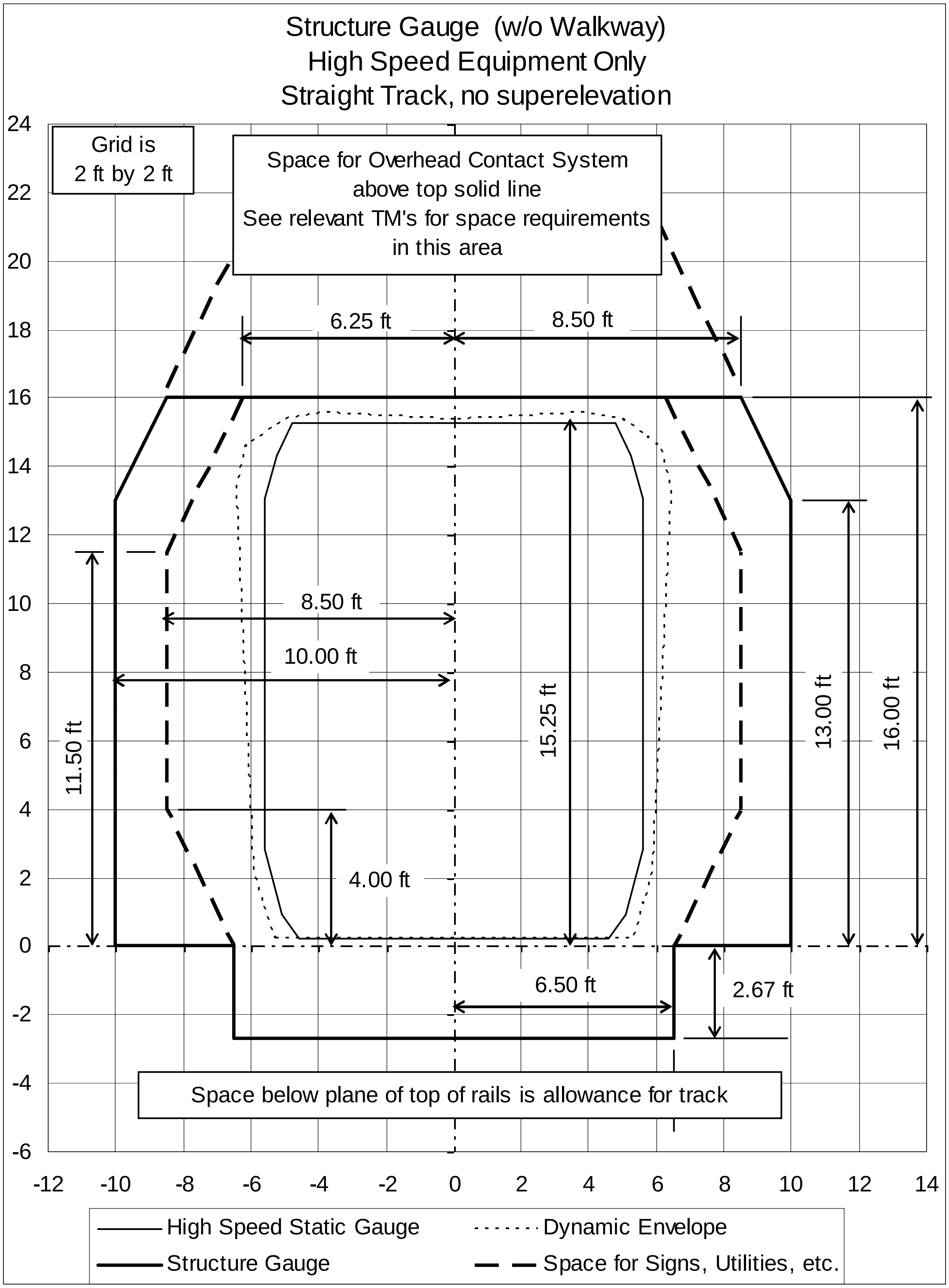
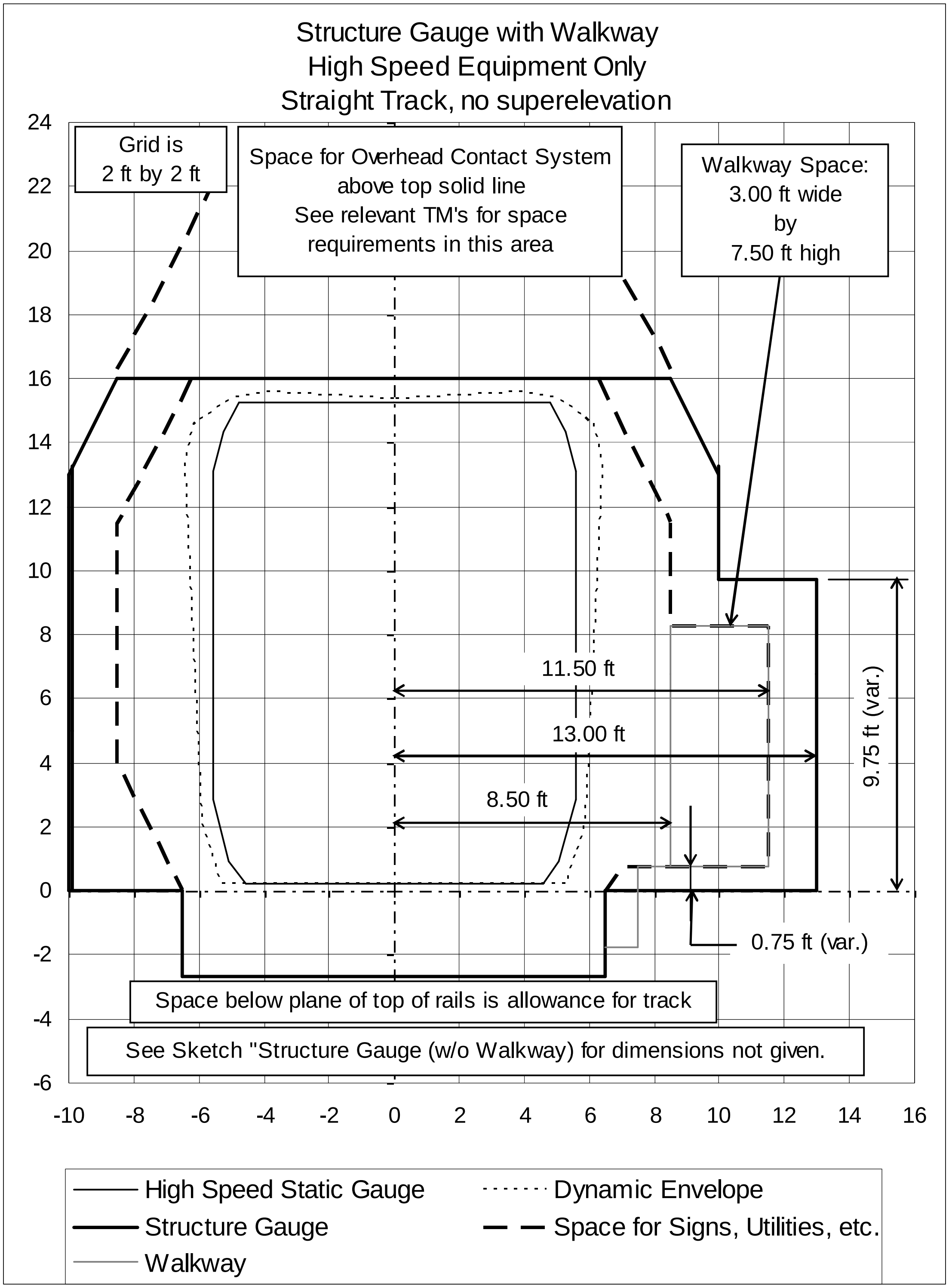
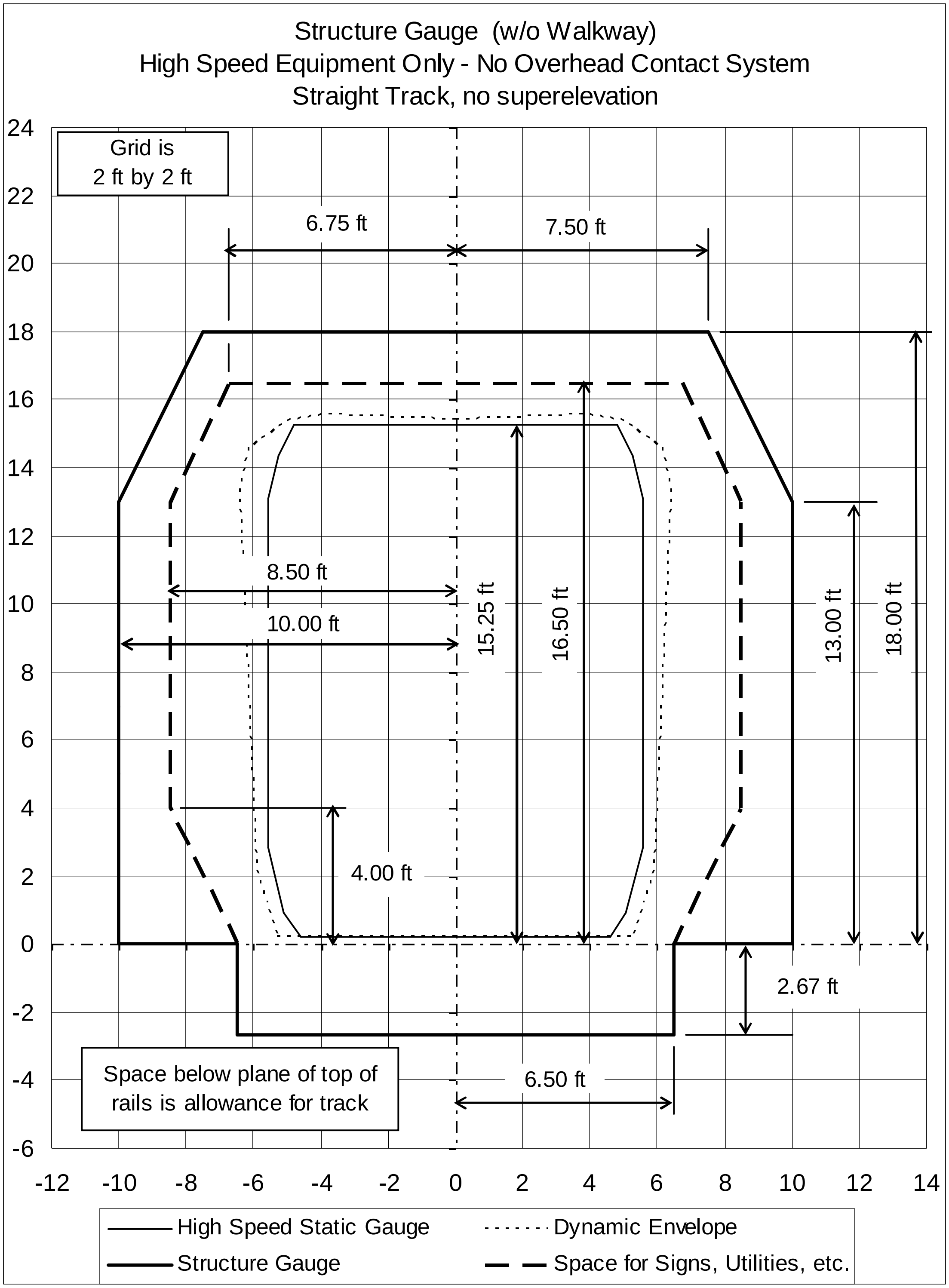


Figure 6.3.4: High-Speed Only Structure Gauge – With Walkway



Certain tracks in yard and shop areas will not have overhead electrification. For these tracks a Structure Gauge no smaller than Figure 6.3.5 shall be applied. This Structure Gauge shall be widened the same as other High-Speed Rail Only Structure Gauges, and shall be rotated in a similar manner in the unlikely event that such a track has any superelevation applied.

Figure 6.3.5: High-Speed Rail Only Structure Gauge – Non-Powered Track – Without Walkway



6.3.7 Structure Gauge Outline Requirements – Curvature and Superelevation Effects

6.3.7.1 Widening of Structure Gauge for Effects of Radius of Curve

Widening of Structure Gauge shall consider lateral clearance issues with any equipment.

Desirable and Minimum Widening: Where unconstrained, the widening shall be such that there will be no lateral clearance issues with any equipment. The widening formula is:

In US Customary units, EO (in inches) = MO (in inches) = 550 / R (in feet).

Expressing the offset requirement in the traditional AREMA format of inches per degree of curve:

EO and MO = $1^1/_8$" x Dc

In order to eliminate the need to increase the section width on all curves, the Structure Gauge widening requirement shall be added to a dimension that is 0.25 feet less than the standard offset.

Table 6.3.1: Additional Width from centerline on Curves – Desirable/Minimum for All Tracks

Curve Radius (feet)	Structure Gauge (feet)	Utility Allowance (feet)	Curve Radius (feet)	Structure Gauge (feet)	Utility Allowance (feet)
2200 plus	10.00	8.50	1300	10.17	8.67
2100	10.01	8.51	1200	10.21	8.71
2000	10.03	8.53	1100	10.25	8.75
1900	10.04	8.54	1000	10.30	8.80
1800	10.06	8.56	900	10.36	8.86
1700	10.07	8.57	800	10.44	8.94
1600	10.09	8.59	700	10.54	9.04
1500	10.12	8.62	600	10.67	9.17
1400	10.14	8.64	500	10.85	9.35

Exceptional Widening Main Tracks, Minimum Widening Yard Tracks: Where constrained, the widening shall be based on the potential EO and MO values for the proposed equipment. Thus, if any longer equipment is operated, it must be narrower than the design vehicle. The widening formula is:

EO (in inches) = MO (in inches) = 500 / R (in feet).

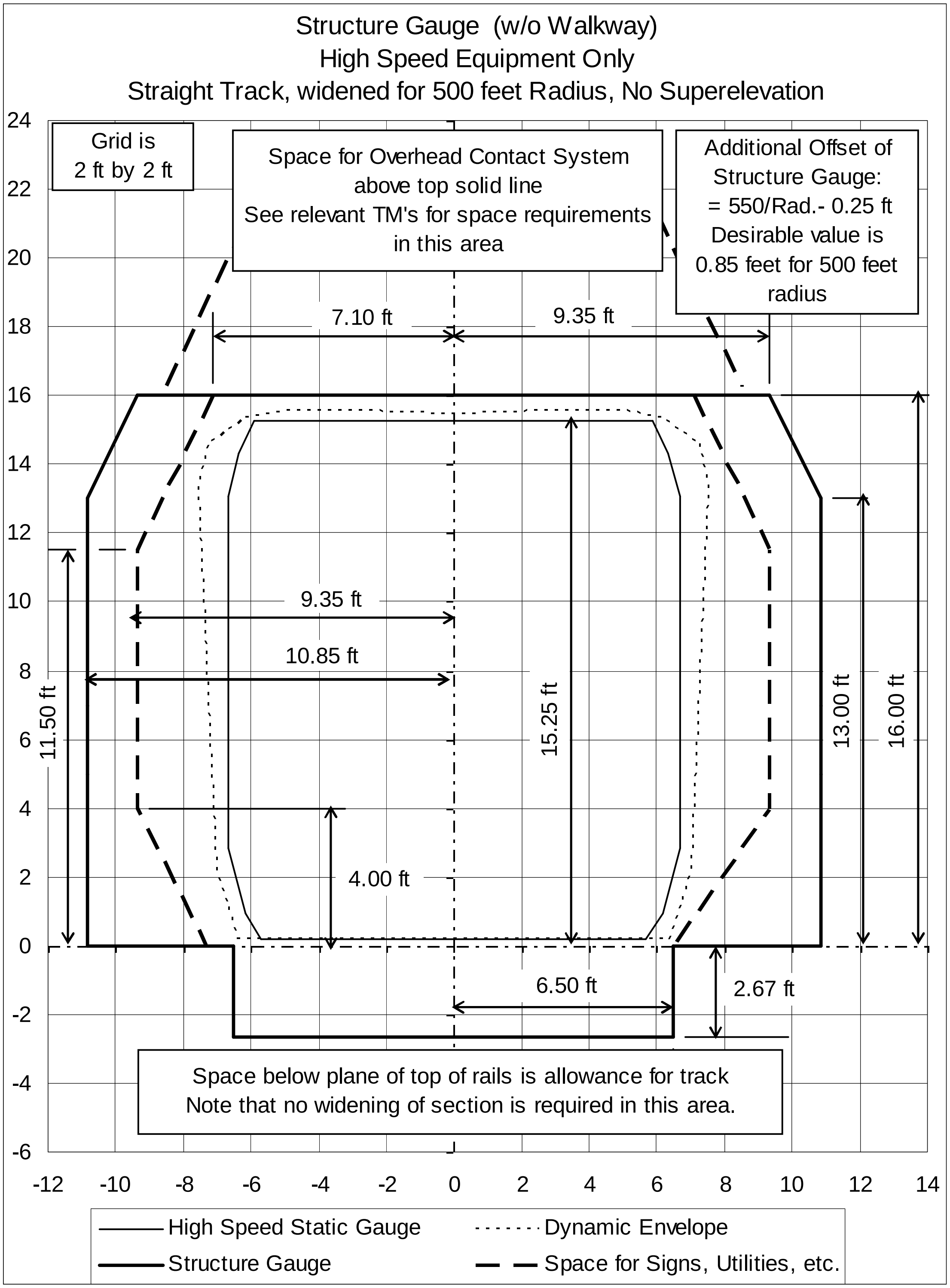
With the widening requirement based on 0.25 feet less than the standard offset, widening need only be applied if the curve radius is less than 2000 feet.

Table 6.3.2: Exceptional Additional Width from Centerline on Curves – High-Speed Tracks

Curve Radius (feet)	Structure Gauge (feet)	Utility Allowance (feet)	Curve Radius (feet)	Structure Gauge (feet)	Utility Allowance (feet)
2000	10.00	8.50	1200	10.17	8.67
1900	10.01	8.51	1100	10.20	8.70
1800	10.03	8.53	1000	10.25	8.75
1700	10.04	8.54	900	10.31	8.81
1600	10.06	8.56	800	10.38	8.88
1500	10.08	8.58	700	10.46	8.96
1400	10.11	8.61	600	10.58	9.08
1300	10.13	8.63	500	10.75	9.25
2000	10.00	8.50	1200	10.17	8.67
1900	10.01	8.51	1100	10.20	8.70

Location of Placement of Transition to Increased Width in Structure Gauge: The usual object is to ensure sufficient space, not a precise need for additional space. Sufficiency can be achieved by beginning the transition from the unwidened section 75 feet into the straight track beyond the beginning of the spiral, or of the curve if there is no spiral and achieving the full needed additional offset not less than 25 feet before the beginning of the full arc.

Figure 6.3.6: Example of Widened Structure Gauge – Radius 500 feet



6.3.7.2 ROTATION OF STRUCTURE GAUGE FOR EFFECTS OF SUPERELEVATION

Point of Definition of Track Profile (PGL): The track profile elevation is defined as the elevation of the top of the inside rail of the curve. This point is commonly referred to as the Profile Grade Line (PGL).

Superelevation Measurement: Superelevation is measured, whether with a level board or by survey, by determining the relative difference in elevation between the highest point on the outside rail of the curve and the highest point on the inside rail of the curve. The distance between the points is normally considered as being track gauge plus rail head width. These high points are slightly further apart than the centerline to centerline separation of the railheads due to the rail inclination toward the track center, but this small distance is normally neglected as being insignificant. Standard track gauge is 56.5 inches (4.71 feet), measured between points 5/8 inch (0.052 feet) below the top of rail. Nominal rail head width is 3 inches. Thus the distance between points of measurement in the superelevation calculation is taken as being 59.5 inches (4.96 feet).

Point of Rotation: The point of rotation of the track is defined as the gauge corner of the inside rail of the curve. Therefore, the point of rotation is at the profile line elevation and offset 2.354 feet from the track centerline toward the inside of the curve.

Walkways: If the walkway is on the outside of superelevated curves, the offset of the walkway will be the same as on straight track except along small radius curves that require widening of the clearance section. If the walkway is on the inside of the superelevated curve, the track side of the walkway will be located based on the position of the utility allowance at a point not lower than 6.00 feet above the walkway surface or top of rail, whichever is higher.

Widening of Section: If the curve radius is small, widening of the section as described in 6.3.7.1, Widening of Structure Gauge for Effects of Radius of Curve and as shown in Table 6.3.1 or Table 6.3.2, as applicable shall be done before the section is rotated. The rotated sections shown in Figures 6.3.7, 6.3.8, 6.3.9, and 6.3.10 show the location of points A, B, B' C, D, and E that may define offset requirement to various facilities located close to the tracks.

OCS Considerations: In order to keep the allowance for the OCS as low as practical, the top line shall remain level on the outside of the curve beyond a point that is offset 4.00 feet from the centerline of the top of the section and perpendicular to that line.

Tabulation: Table 6.3.3 provides dimensions for these locations for the superelevated condition at varying superelevations from zero to 7 inches in full inch increments. The X values are the lateral distance from vertical centerline, without sign, and the Y values are the elevation above top of low rail of the curve. The walkway height may vary from that given in this example.

Table 6.3.3: Points Around Unwidened and Rotated High-Speed Only Structure Gauge

Ea (inch)	A		B		B'		C		D		E	
	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
0	10.000	0.000	8.500	16.000	4.000	16.000	0.000	16.000	8.500	16.000	13.000	9.750
1	9.998	0.208	8.269	16.104	3.730	16.104	0.269	16.038	8.768	15.894	13.114	9.750
2	9.993	0.415	8.038	16.204	3.458	16.204	0.539	16.070	9.034	15.784	13.231	9.750
3	9.984	0.623	7.808	16.300	3.185	16.300	0.810	16.098	9.299	15.670	13.348	9.750
4	9.972	0.831	7.578	16.391	2.910	16.391	1.081	16.122	9.562	15.551	13.468	9.750
5	9.957	1.038	7.348	16.478	2.633	16.478	1.353	16.141	9.823	15.427	13.591	9.750
6	9.937	1.246	7.118	16.559	2.354	16.559	1.626	16.156	10.083	15.298	13.716	9.750
7	9.914	1.453	6.890	16.637	2.073	16.637	1.898	16.166	10.340	15.166	13.843	9.750

No table is given for the combination of widened and superelevated sections. For the combined condition the values can be calculated using the various formulae given, as the offset of the various points will vary with radius.

Sample Sections of Superelevated Structure Gauges: The following sections show standard Structure Gauges for High-Speed Tracks as affected by superelevation and widening. Only the extreme cases of superelevation and the combination of superelevation and widening are shown. For the effects of other values of superelevation and widening, see the appropriate tables, or calculate values using the information given above. The first set of Structure Gauge Outlines, Figures 6.3.7 and 6.3.8 illustrates these sections without provision of walkway space to show shapes and dimensions of the portions of the Structure Gauge not affected by the presence of the walkway. Figures 6.3.9 and 6.3.10 illustrate the walkway and show only those dimensions relevant to the walkway.

Figure 6.3.7: High-Speed Only Structure Gauge – Without Walkway Rotated for 7" Superelevation

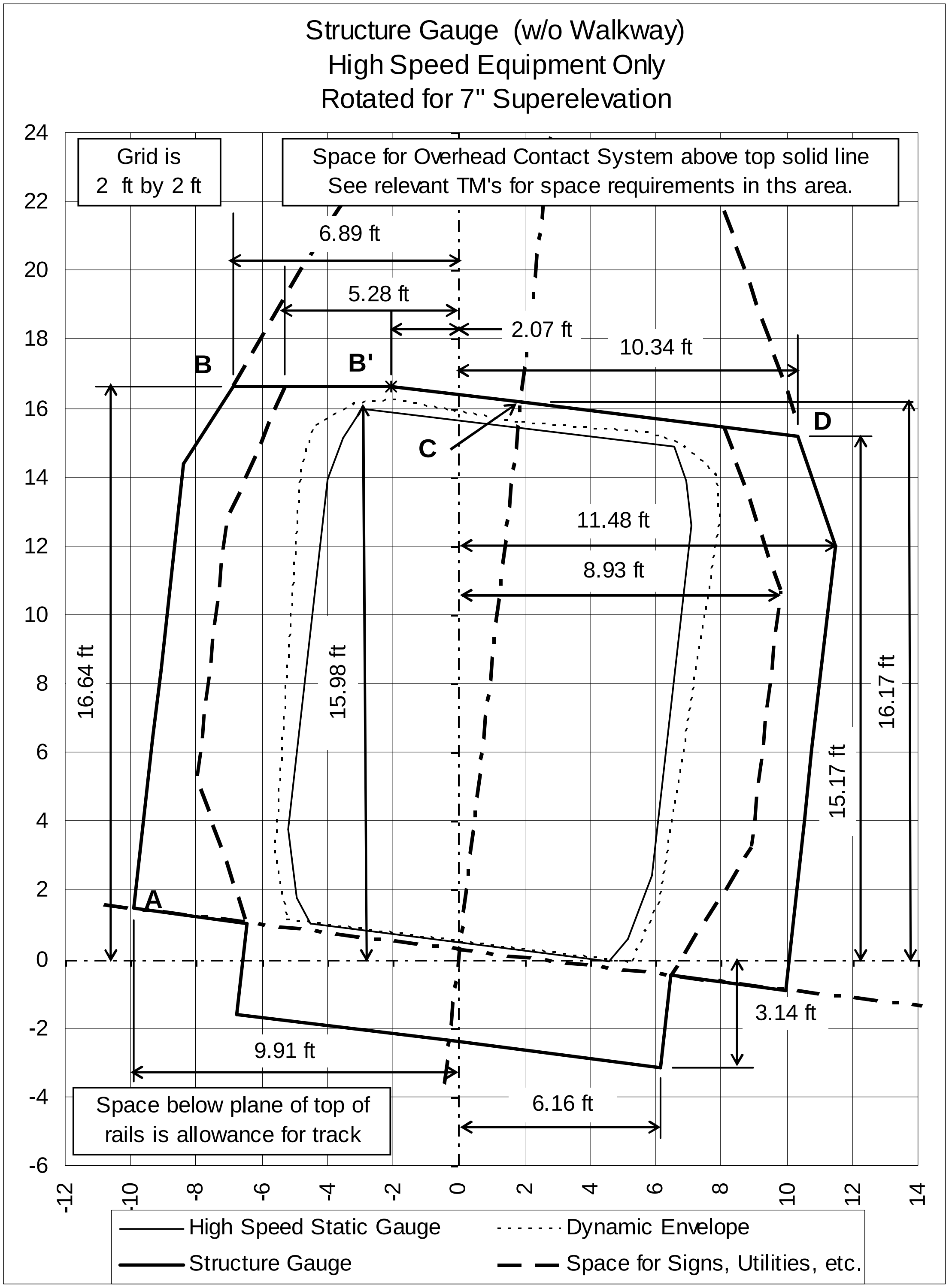


Figure 6.3.8: High-Speed only Structure Gauge – Without Walkway Widened for 500' Radius and Rotated for 7" Superelevation

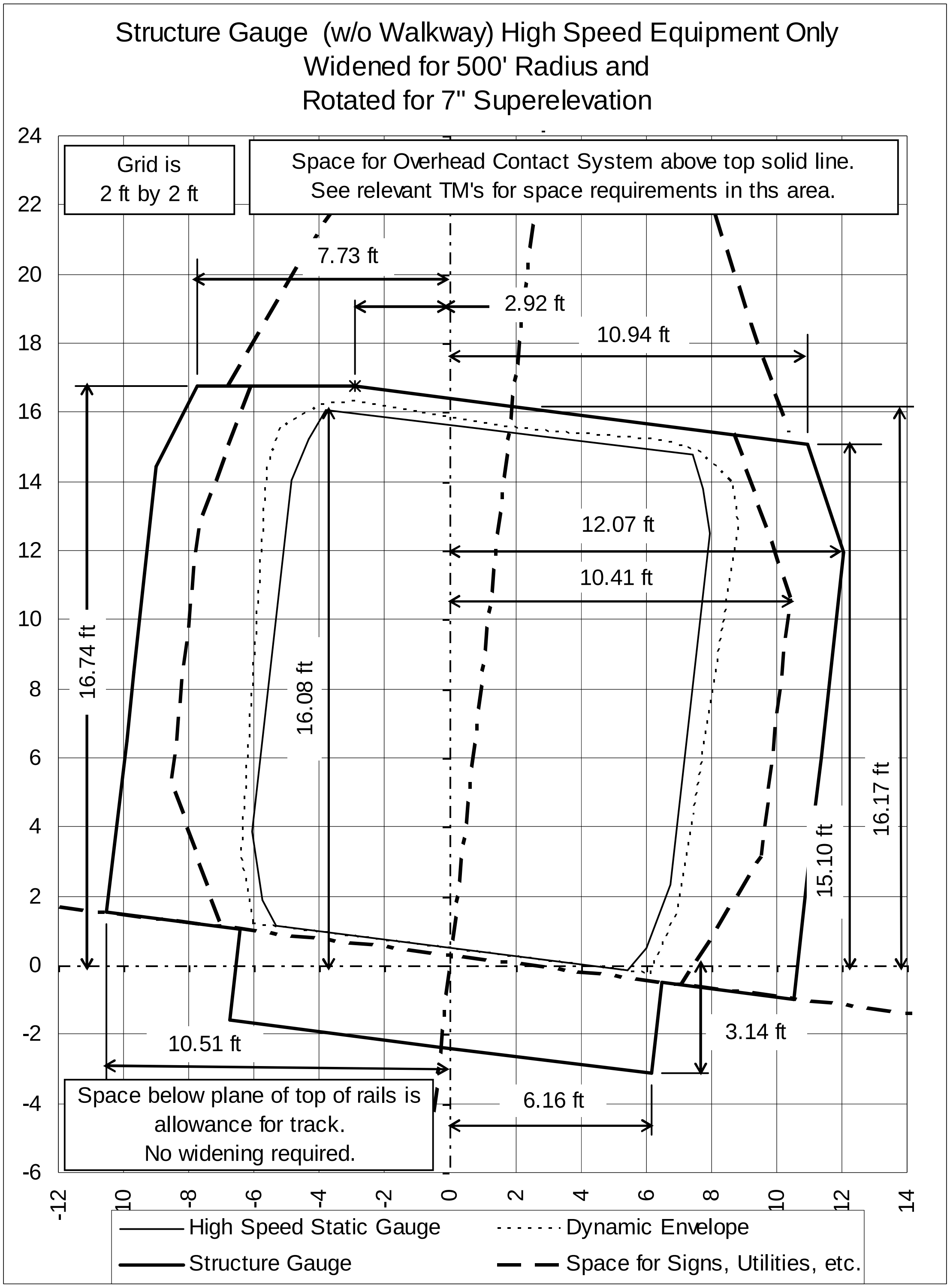
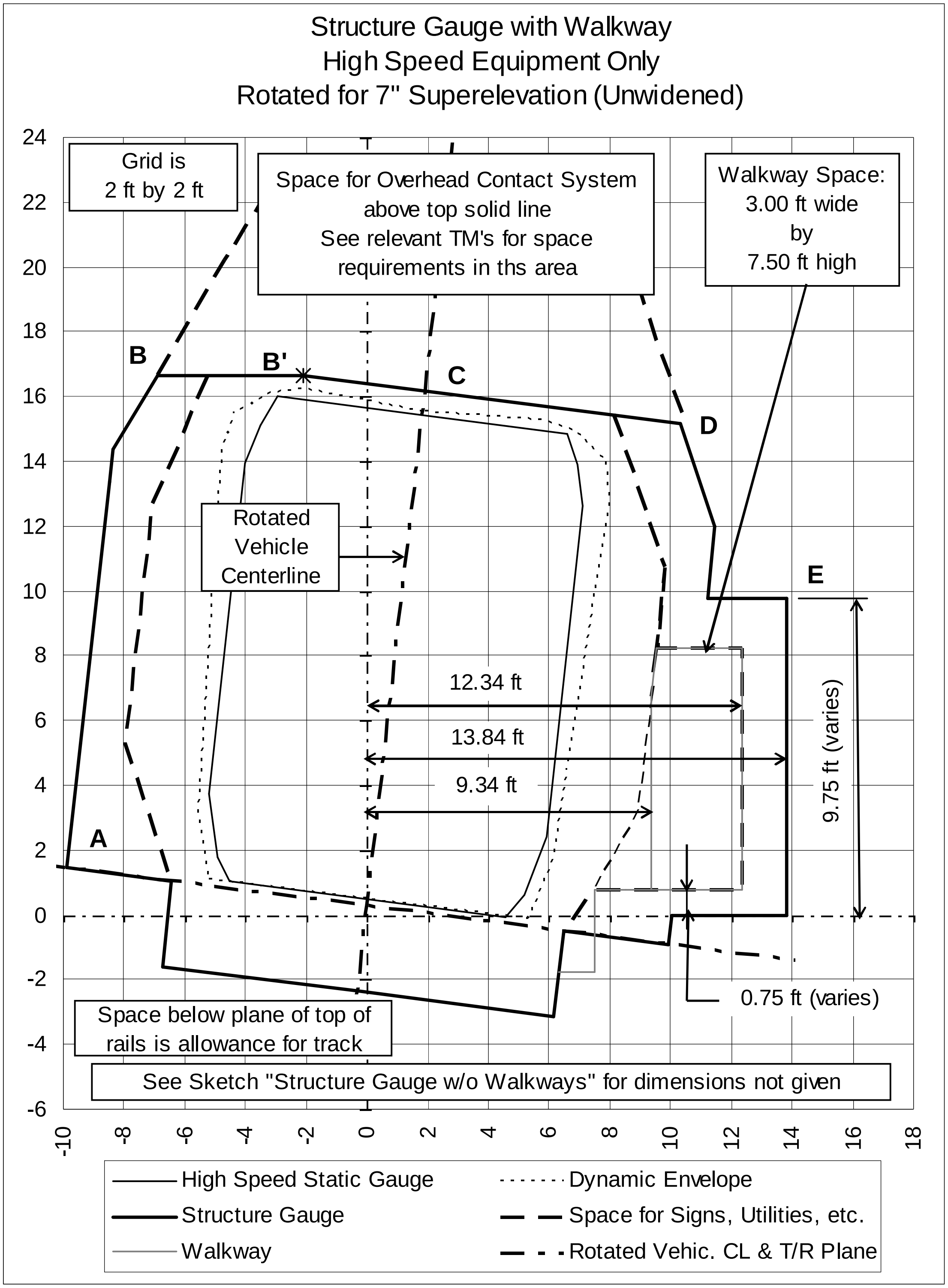


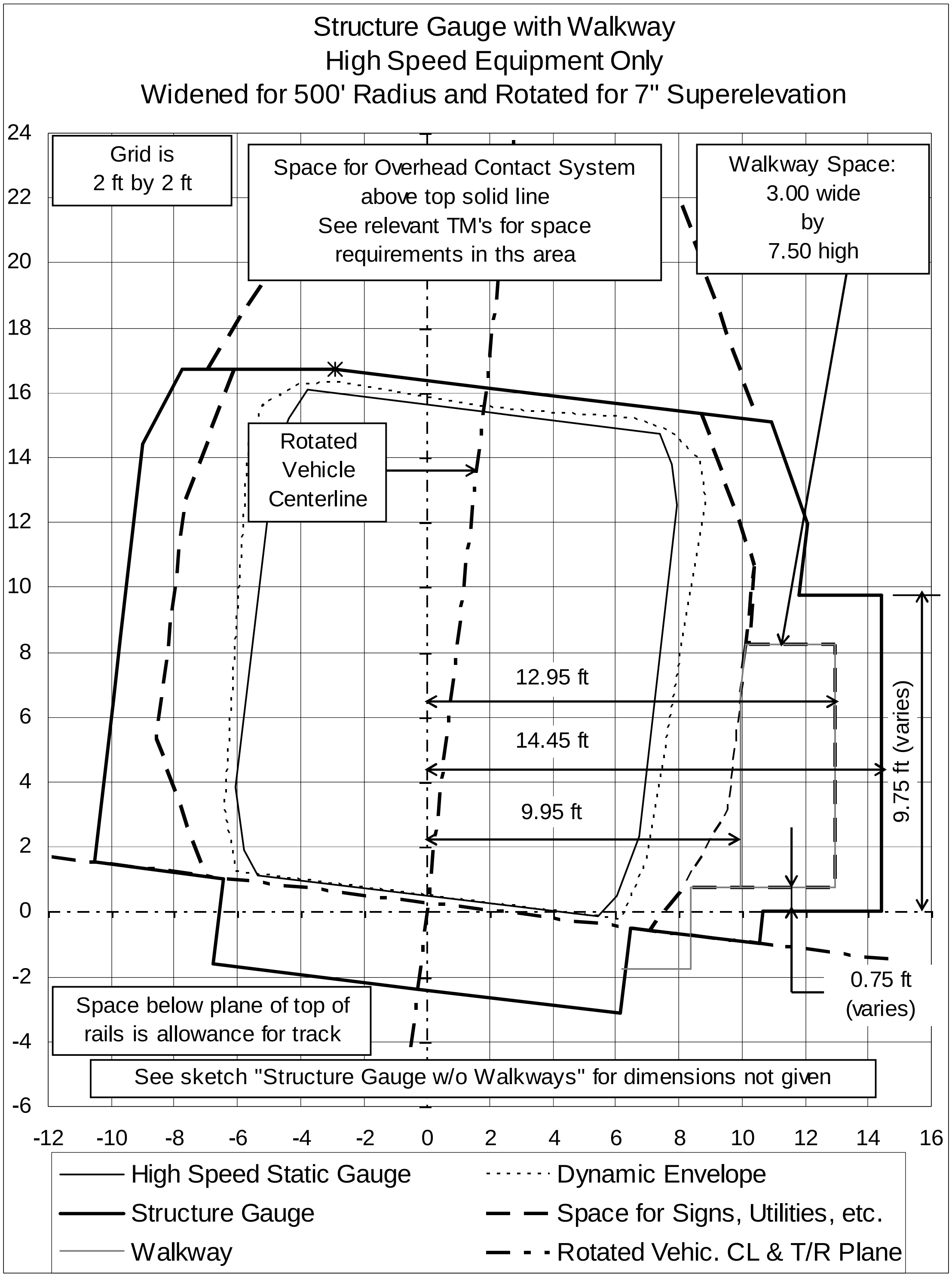
Figure 6.3.9: High-Speed Only Structure Gauge – With Walkway Rotated for 7" Superelevation



Notes:

1. If walkway is on the high side of the curve, offset from track is unaffected by superelevation.
2. Minimum offset of track side of walkway is Utility Allowance offset at a point 6.00 feet above bottom of walkway.

Figure 6.3.10: High-Speed Only Structure Gauge – With Walkway Widened for 500 feet Radius and Rotated for 7" Superelevation



Notes:

1. If walkway is on the high side of the curve, offset from track is unaffected by superelevation but is affected by widening of section due to the radius effect.
2. Minimum offset of track side of walkway is Utility Allowance offset at a point 6.00 feet above bottom of walkway.

6.3.8 Station Platforms

Station Platform offsets and elevations will be specific to the equipment operated. Since the type of equipment is unknown at this time, the platform edge location specific to the CHSTP can not be finalized in this Technical Memo. The relationship between car floor and passenger platform is governed by FRA requirements as given in 49CFR Part 38, Americans with Disabilities Act (ADA) Accessibility Specifications for Transportation Vehicles, paragraph 38.175, which in part states as follows:

> (a) All cars for high-speed rail systems, including but not limited to those using "maglev" or high speed steel-wheel-on-steel rail technology, and monorail systems operating primarily on dedicated rail (i.e., not used by freight trains) or guideway, in which stations are constructed in accordance with part 37, subpart C of this title, shall be designed for high-platform, level boarding . . . The design of cars shall be coordinated with the boarding platform design such that the horizontal gap between a car door at rest and the platform shall be no greater than 3 inches and the height of the car floor shall be within plus or minus 5/8 inch of the platform height under all normal passenger load conditions. Vertical alignment may be accomplished by car air suspension or other suitable means of meeting the requirement. All doorways shall have, when the door is open, at least 2 foot-candles of illumination measured on the door threshold.

Part 37, Subpart C referenced above states that the above requirements are in effect for all intercity rail stations constructed since 1991 and provides a number of requirements for other station facilities that are irrelevant to the issue of clearances.

Design Values for offset and elevation shall be set to be sufficiently less than the FRA requirement to ensure that construction and maintenance tolerances and equipment movements during normal operations do not result in a non-compliant gap.

Until such time that the equipment selected is finalized, the track side edge of the platform shall be regarded as being located 5.75 feet offset from centerline and 4.25 feet above top of rail. These dimensions are selected as they represent the widest equipment and highest car floor elevation likely to be used, and will therefore result in the greatest width of "footprint" for the platforms.

APPENDICES

X.1 GENERAL

X.1.1 Background

It is important to understand the difference between a Clearance Diagram and a Structure Gauge. Frequently these terms are used as if they are interchangeable, but they are not. A Structure Gauge defines the minimum distance to any facility next to the track or equipment. The Clearance Diagram usually defines the limits to which major structures may be built, but inside that line will frequently be minor features such as signs and signals. Clearance Diagrams as shown in the AREMA Manual tend to be treated as if they are Structure Gauges, but sometimes items are attached to tunnel walls and bridges that fall inside these lines.

X.1.2 Discussion

Lack of understanding of the purpose and applicability of Structure Gauges and Clearance Diagrams causes frequent difficulties during the design process that can and should be avoided. The primary purpose of any Structure Gauge is to ensure that the constructed facilities do not under any conceivable circumstances interfere with the movement of any equipment that is anticipated to be operated on the track to which it is referenced. Therefore, a limited amount of excessive offset in the Structure Gauge is not normally a concern, so in case of doubt, it is better to err in the direction of more clearance rather than less clearance. There are however, some facilities whose proximity and clearance are both of concern, such as public platforms, and access platforms in shop and maintenance facilities.

Structure Gauges and Clearance Diagrams are also found to commonly be undersized due to the need for equipment and facilities not considered at the time that they were developed. Particularly in the case of tunnels, enlarging the cross section later can be prohibitively expensive. Therefore, it is always desirable to resolve uncertainties in the direction of making the section larger rather than smaller. The growth in recommended clearances in the AREMA Manual and in the standards of various railroad companies over the years illustrates that the various railroad operating companies have considered it worthwhile to spend large sums of money to increase both overhead clearances and the spacing between cars and fixed facilities. While much of the increase is related to the need for increased height to clear the higher cars and loads being handled with the advent of three level automobile carriers, intermodal, and double stacked containers; the increase in required lateral offset is not related to larger vehicles. Railroad cars and engines are no wider now than they were 100 years ago, yet the required offset between track and adjacent fixed facilities and between track centers has increased, in some cases considerably increased.

Current standard of many railroad companies is to require no less than 25.00 feet lateral clearance between the center of any main track and any bridge pier or structure. However, this space is used to provide space for off-track work equipment, reduce the possibility of collision in case of derailments or shifted load, to improve sight lines and to contain signals and other railroad related facilities, not all of which would be applicable to the CHST system.

X.2 LEGAL AND ASSOCIATION REQUIREMENTS

There are no US Federal requirements that apply to clearances for a High-Speed Rail System.

X.2.1 California Public Utilities Commission (CPUC) General Order (GO) 26-D Requirements

There are certain very specific requirements in CPUC GO 26 that shall be met as an absolute minimum.

The general minimum side clearance from center of track is 8.50 feet, given in Section 3. This requirement is for railroads that carry freight. There are also specific requirements for railroads that do not carry freight. Specifically, in sub-section 9.2:

> 9.2 Minimum side clearances of railroad and street railroad tracks which are not used or proposed to be used for transporting freight cars shall be thirty (30) inches from the side of the widest

equipment operated, except that for poles supporting trolley contact conductors between main line double tracks such distance may be decreased to twenty-four (24) inches.

Section 5-Clearance Between Parallel Tracks

5.1 The minimum distance between the center lines of parallel standard gauge tracks shall be fourteen (14) feet except as hereinafter provided.

5.2 The center line of any standard gauge track, except a main track or a passing track, parallel and adjacent to a main track or a passing track, shall be at least fifteen (15) feet from the center line of such main track or passing track; provided, however, that where a passing track is adjacent to and at least fifteen (15) feet distant from the main track, any other track may be constructed adjacent to such passing track with clearance prescribed in subsection 5.1 of this order.

5.3 The center line of any standard gauge ladder track, constructed parallel to any other adjacent track, shall have a clearance of not less than twenty (20) feet from the center line of such other track.

5.4 The minimum distance between the center lines of parallel team, house and industry tracks shall be thirteen (13) feet.

5.5 Main, siding and yard tracks constructed prior to the effective date of this order with distance of not less than thirteen (13) feet between track centers may be extended without increasing such distances.

Section 10—Clearance Between Parallel Tangent Tracks

The minimum distance between the center lines of parallel tangent tracks shall be not less than the width of the widest car operated plus twenty-four (24) inches.

Since this minimum spacing does not leave a sufficiently wide pathway between cars, it will not be a governing dimension for the CHSTP.

There is also a minimum overhead clearance requirement for passenger only lines of 14.00 feet, however since this is based on the old standard maximum height of passenger car of 13.50 feet or less and a non-electrified system, it is of no significance to the CHSTP. There are specific allowances for reduced clearances in the upper and lower corners. Should raised walkways or cable troughs be desired, their offset would be governed by the provisions of sub-section 9.4:

9.4 Minimum side clearances as prescribed in this section may be decreased in bridges, tunnels or subways to the extent defined by a line extending diagonally upward from a point level with the top of rail and five (5) feet distant laterally from the center line of track to a point four (4) feet above the top of rail and distant laterally thirty (30) inches from the side of the widest equipment operated.

Minimum Lateral Offset: Since the widest anticipated equipment is the Shinkansen equipment, 11.15 feet wide, the minimum side clearance to any object would be 5.58 feet plus 2.50 feet equals offset to 8.08 feet. This dimension does not include allowance for curvature or tolerances. Therefore, a larger dimension should be used as the standard. Use of 8.50 feet as the minimum offset dimension eliminates the necessity of widening the section for the radius effect on most curves.

Minimum Vertical Offset: The purpose of this Technical Memo in the vertical direction is only to define the upper limit of the portion of the Structure Gauge occupied by features below the reservation for the overhead line facilities. CPUC GO 26D is not relevant to that issue.

Passenger Platform Positioning: While passenger platforms are not part of the subject of this Technical Memo, they are one of the subjects covered in CPUC GO 26D. In the GO, passenger platforms are described as an exceptional condition, as follows in sub-section 11.1:

11.1 Minimum clearances prescribed in Sections 9 and 10 of this order may be reduced along passenger platforms subject to approval by the Commission.

There are general requirements for passenger platform offsets given in Section 3. Following these requirements would eliminate the need for Commission approval, but following these requirements does not result in a good match between train floor and platform, nor would it comply with the Americans with Disabilities Act (ADA), which effectively pre-empts the CPUC requirement.

X.2.2 Americans With Disabilities Act (ADA) Requirements

The ADA requirements are given in 49 CFR Part 38 — Americans with Disabilities Act (ADA) Accessibility Specifications for Transportation Vehicles. Paragraph 38.53, Doorways, (d), states in part:

> (d) *Coordination with boarding platform*
>
> (1) *Requirements:* . . . Where new vehicles will operate in new stations, the design of vehicles shall be coordinated with the boarding platform design such that the horizontal gap between each vehicle door at rest and the platform shall be no greater than 3 inches and the height of the vehicle floor shall be within plus or minus 5/8 inch of the platform height under all normal passenger load conditions.

Requirements specific to High-Speed Rail are the same and are given in paragraph 38.175, High-speed rail cars, monorails and systems, which in part states as follows:

> (a) All cars for high-speed rail systems, including but not limited to those using “maglev” or high speed steel-wheel-on-steel rail technology, and monorail systems operating primarily on dedicated rail (i.e., not used by freight trains) or guideway, in which stations are constructed in accordance with part 37, subpart C of this title, shall be designed for high-platform, level boarding . . . The design of cars shall be coordinated with the boarding platform design such that the horizontal gap between a car door at rest and the platform shall be no greater than 3 inches and the height of the car floor shall be within plus or minus 5/8 inch of the platform height under all normal passenger load conditions. Vertical alignment may be accomplished by car air suspension or other suitable means of meeting the requirement. All doorways shall have, when the door is open, at least 2 foot-candles of illumination measured on the door threshold.

X.2.3 AREMA Requirements

The AREMA Manual, Chapter 28, Part 1, provides several Clearance Diagrams. While the height of these diagrams is of no particular significance to the High-Speed Rail, the width and the changes in width over time is of interest. The current lateral dimension of 9.00 feet were revised in 1983 from the previous 8.50 feet lateral offset from centerline which was itself increased from the 8.00 feet lateral offset that prevailed for many years. Standard American freight cars are normally 10.67 feet wide and have been since long before the 8.00 feet width became standard.

The current AREMA Clearance Diagrams are not necessarily the same as those used by the various railroad companies. Frequently the section widths required by the various major railroad companies for their main tracks are greater than those in the AREMA Manual. The standards are significant because they indicate what experienced operators consider to be sufficient working space around their tracks.

X.3 STRUCTURE GAUGES FROM OTHER SYSTEMS

X.3.1 Shinkansen Structure Gauge

The Shinkansen System Structure Gauge has multiple lines for various applications, including open air sections, bridges, tunnels, shops, platforms, etc. For clarity only the lines applicable to open air sections including through bridges are shown solid, tunnels with a heavy dash, and platforms and platform railings and canopies with a light dash are shown on the figure below. The gauge in figure 3.5.1 is that applicable to straight track.

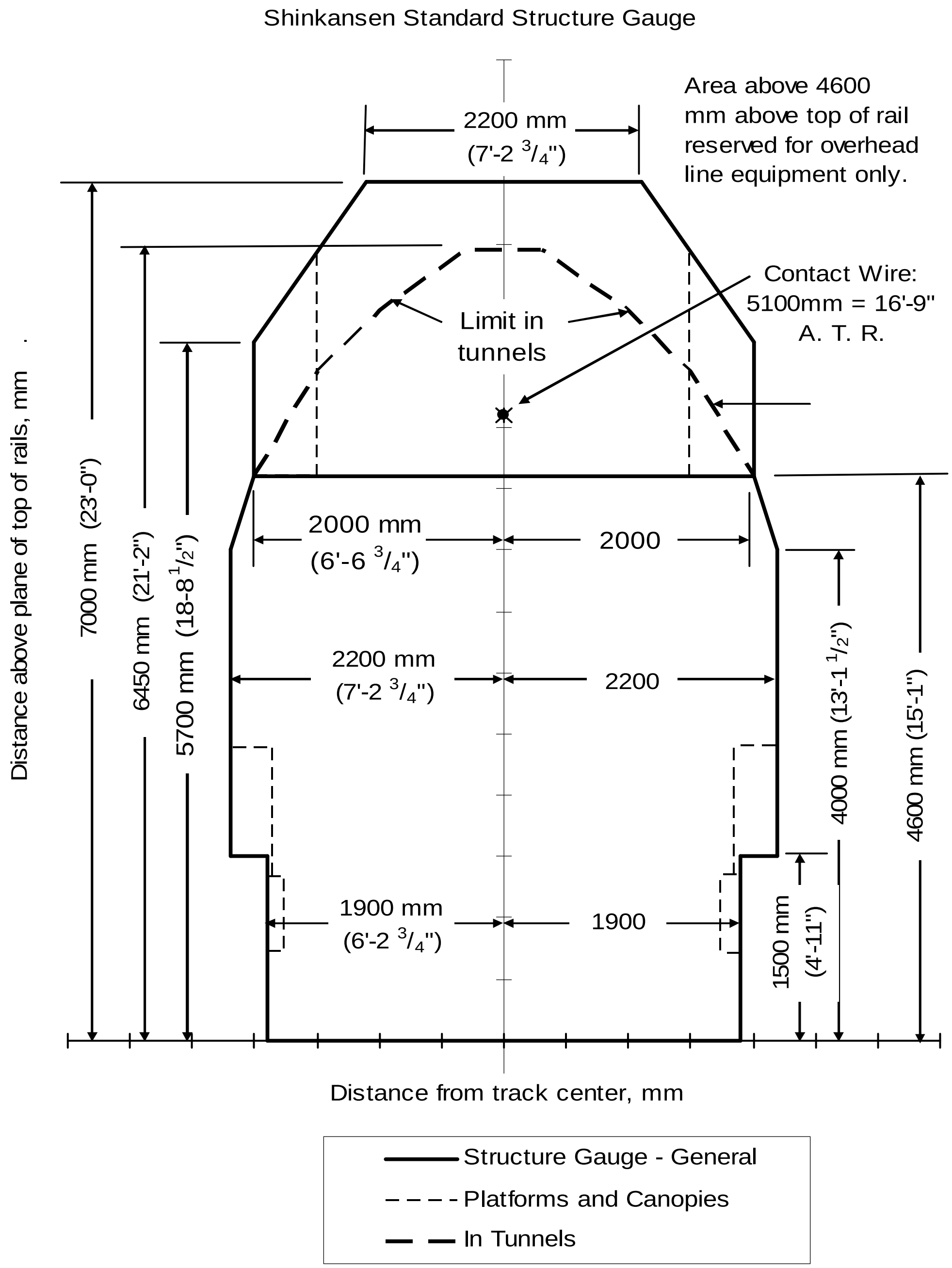
The Shinkansen Gauges and other that were originally developed using metric dimensions will be presented with the metric units first and the closest equivalent US Customary unit in parenthesis adjacent to or beneath the metric dimension. The metric dimension is the defining dimension.

The Structure gauge is slightly over 300 mm (0.98 feet) clear of the Dynamic Envelope of these vehicles in the wider portion, but only 100 mm (0.33 feet) clear of the Dynamic Envelope at the top of the narrow bottom section. These clearances are less than PUC requirements from the Static Vehicle.

The narrower bottom section is typical in Structure Gauges developed for systems using high level platforms and half-through girder bridges. The preferred height of the structure gauge in Japan is 7700 mm (25.26 feet), with the reduction to 7000 mm (22.97 feet) being permitted where the catenary may be attached to overhead structures, whether overpasses or through truss bridges.

The line separating the clear area allowed for the vehicle and the area reserved for their Overhead Contact System is only 107 mm (0.35 feet) above the top of the highest vehicles operated on their system. It is lower than the top of the Dynamic Envelope that was developed for these same vehicles used on the Taiwan High-Speed Railway. This suggests that either the Dynamic Envelope was too tall or else the vehicle will under certain conditions encroach into their OCS reservation.

Figure X.3.1: Shinkansen Standard Structure Gauge – as Applied in Taiwan



In normal practice, the actual structure outline will be offset some distance, usually not less than 300 mm (12 inches) beyond the line of this structure gauge to permit the installation of cables, signals, signs, etc. within the structure.

For use on curves the section is widened and rotated as appropriate for radius and superelevation. The widening in the Japanese requirement is calculated by Offset (mm) = 50,000 / Radius (m) approximately Offset (inches) = 6,500 / Radius (feet), which is greater than the mid-car / end-car swings of the coaches. The additional offset appropriate to the vehicle itself is closely described by Offset (mm) = 40,000 /

Radius (m) or Offset (inches) = 5,200 / Radius (feet). For curves with superelevation, the widening of the section must be calculated, and then the section rotated about the low rail of the curve by the appropriate amount. The higher portion of the section designated as being for electrical equipment only does not require widening for radius. For large radius high speed curves the widening is insignificant. See Table X.3.1 for the effects of rotation at various superelevations at the line below the electrical reservation.

Figure X.3.2: Shinkansen Standard Structure Gauge on Superelevated Curve

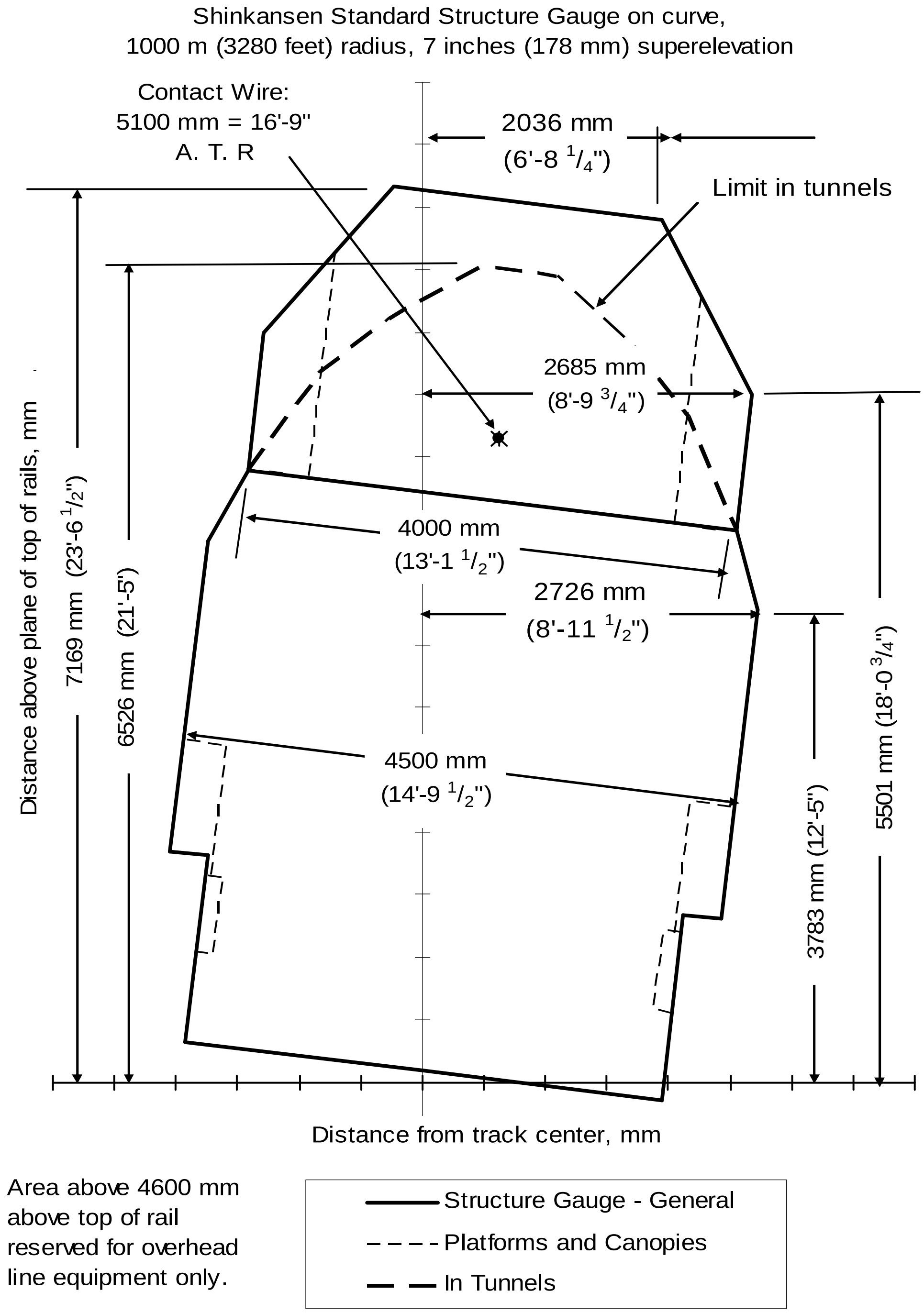


Table X.3.1: Shinkansen Structure Gauge Corner Movement with Superelevation

(millimeters)				(feet)			
Ea	X (from centerline)	Y (above top of rail)	Net Rise	Ea (inches)	X (from centerline)	Y (above top of rail)	Net Rise
0	2000	4600	0	0	6.56	15.09	0
60	1815	4704	104	3	5.95	15.43	0.34
120	1626	4801	201	5	5.33	15.75	0.66
180	1433	4891	291	7	4.70	16.05	0.95

X.3.2 Taiwan High-Speed Railway

The Taiwan High-Speed Railway (HSR) did not have a Structure Gauge in their Design Criteria. One was developed later, and in final form was the outline shown in Figure 3.5.1. The Design Specification, as the document was titled, had two simple tables as shown in Figure 3.5.3.

Figure X.3.3: Taiwan HSR Clearance Requirements

Table 1-4: Lateral Clearances

LATERAL CLEARANCE	SPEED S (km/h)			
	S≤230	S≤270	S≤300	S≤350
from field side of rail head to nearest edge of:				
- walkway on cut/fill/grade	≥ 2.00m	≥ 2.00m	≥ 2.00m	≥ 2.70m
- walkway on structure	≥ 2.00m	≥ 2.00m	≥ 2.00m	≥ 2.40m
from field side of rail head to:				
- abutments of road bridges	≥ 2.80m	≥ 2.80m	≥ 2.80m	≥ 3.20m
- hand rail of rail bridges	≥ 2.80m	≥ 2.80m	≥ 2.80m	≥ 3.20m

Table 1-5: Overhead Clearances for Structures over HSR

Length (L) of the structure above centerline of HSR	Overhead Clearances	
	Running Tracks	Turnout Areas
L ≤ 22.5 m	7.73 m	8.23 m
L > 22.5 m	7.03 m	7.53 m

In exceptional circumstances such as the underground approach tunnels to stations where operating speeds are reduced, overhead clearances less than those given in Table 1-5 may be used upon receipt of written statement of "No Objection" from the ER.

Note in Table X.3.3 that HSR Table 1.4 defines offsets from the "Field side of the rail head". This method of defining offsets led to considerable confusion and should not be used. Offsets should always be defined in relation to track centerline. In addition to these tables there were a number of standard drawings showing cross sections of tunnels, bridge decks and earthworks sections that provided dimensions to cable troughs, catenary poles, bridge railings and other lineside features.

X.3.3 Structure Gauges – EU Technical Specification for Interoperability

There is no clearly defined Structure Gauge in the TSI.

Definition of Structure Gauge in the Infrastructure TSI is limited to the statement that:

"The infrastructure must be constructed so as to allow safe clearance for the passage of trains complying with the High-Speed Rolling Stock TSI" and that it is to be "set out on the basis of the GC reference kinematic profile and the minimum infrastructure lower parts gauge, both described in the High Speed Rolling Stock TSI." The High Speed Rolling Stock TSI contained no such information, but instead contained a statement that:

> "Rolling stock shall comply with one of the kinematic vehicle gauges defined in Annex C of the Conventional Rail Rolling Stock Freight Wagon TSI".

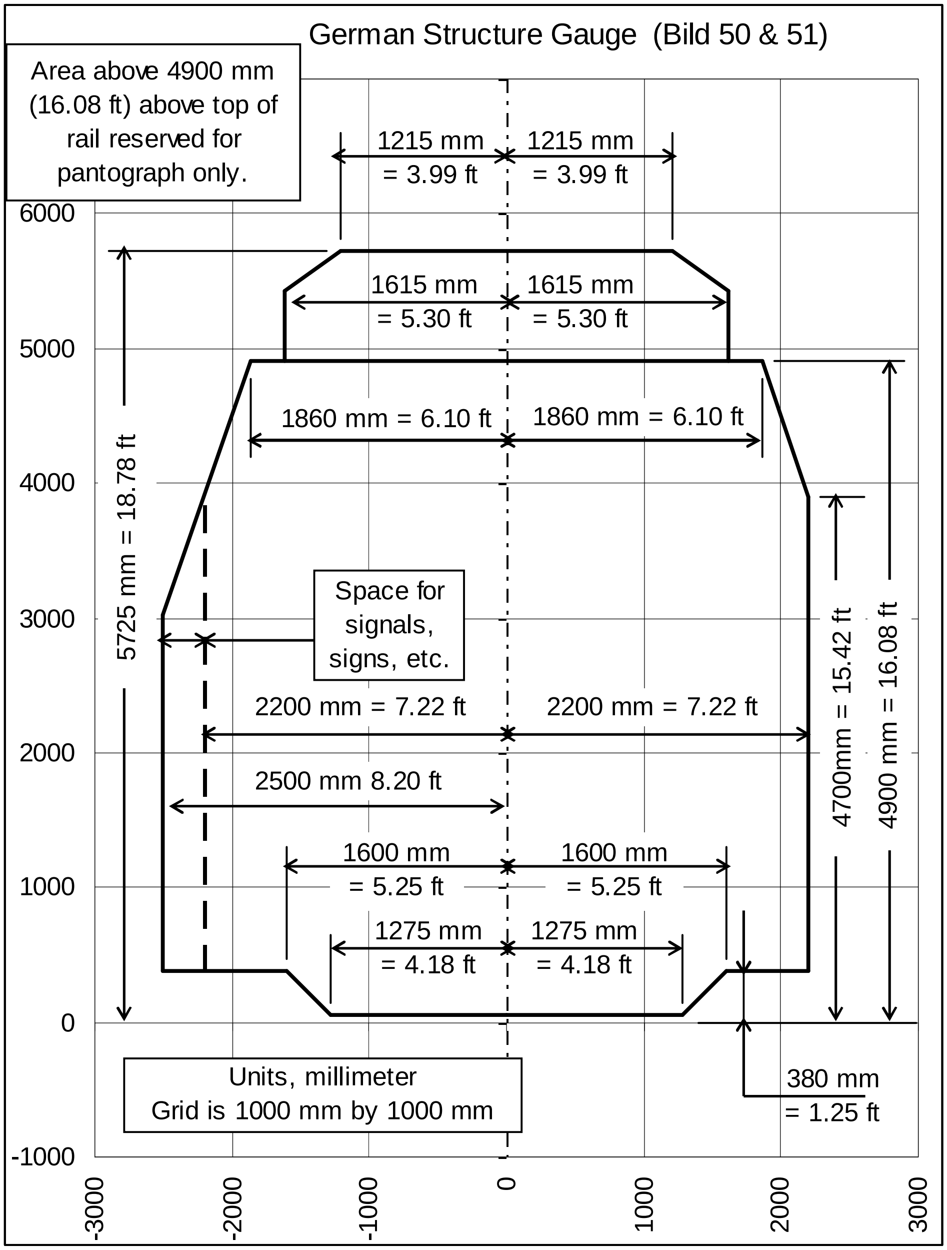
The referenced Annex C provides dimensioned diagrams of both Static and Kinematic (Dynamic) outlines for all the referenced clearance requirements.

The German Structure Gauge appears to be a good example of a Structure Gauge that encapsulates, and is likely derived from, the TSI Kinematic Envelope.

X.3.4 Structure Gauges – German

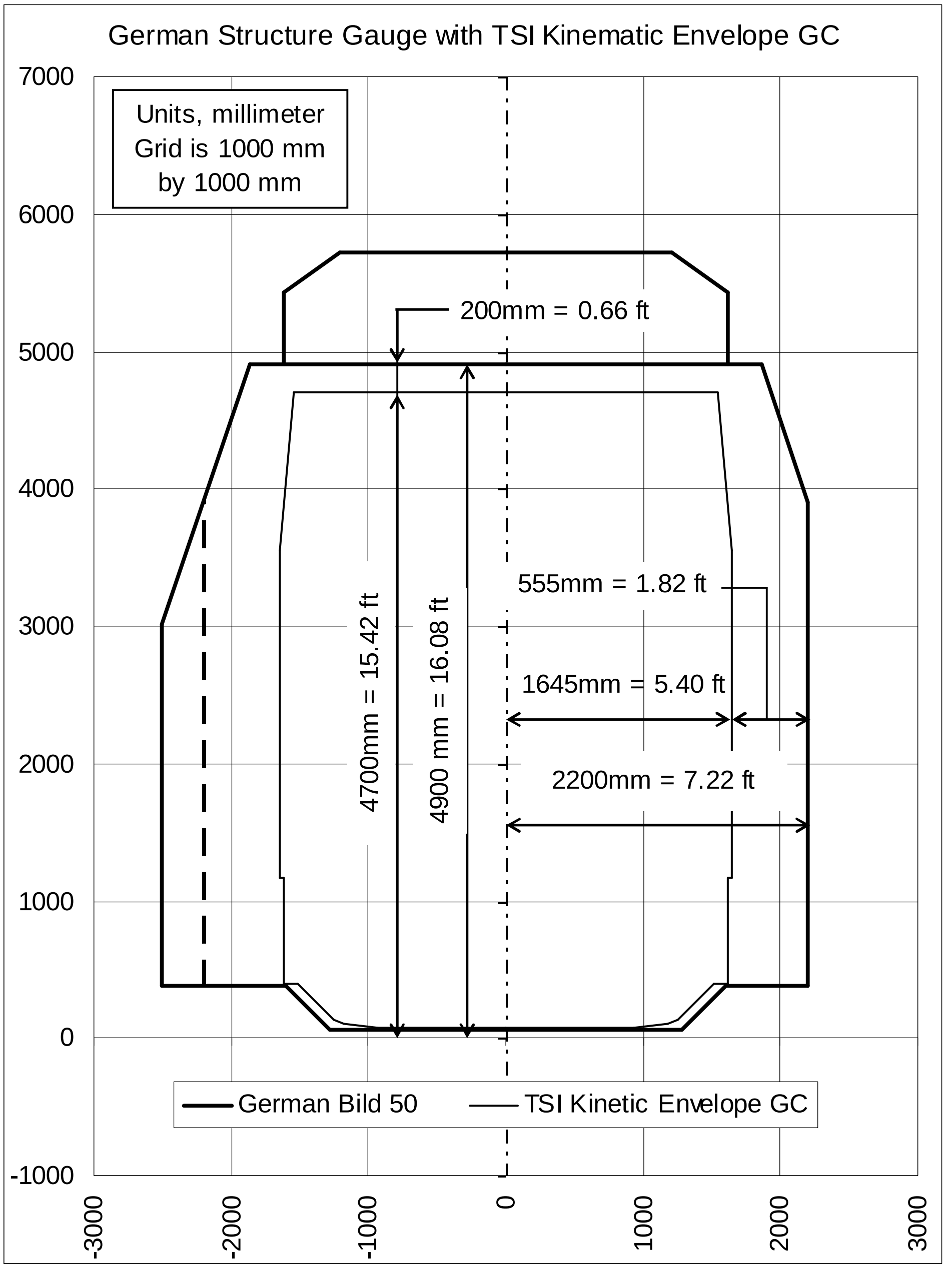
In the German Railway publication DS 804, Vorschrift fur Eisenbahnbrucken und Sonstige Ingenieurbauwerke (VEI) (Regulation for Railway Bridges and other Engineering Works) a structure gauge specific to bridges is provided. Even though their equipment is smaller, the Structure Gauge is larger than the Japanese Shinkansen Structure Gauge. Therefore it is apparent that the German design provides more clear space around the vehicle.

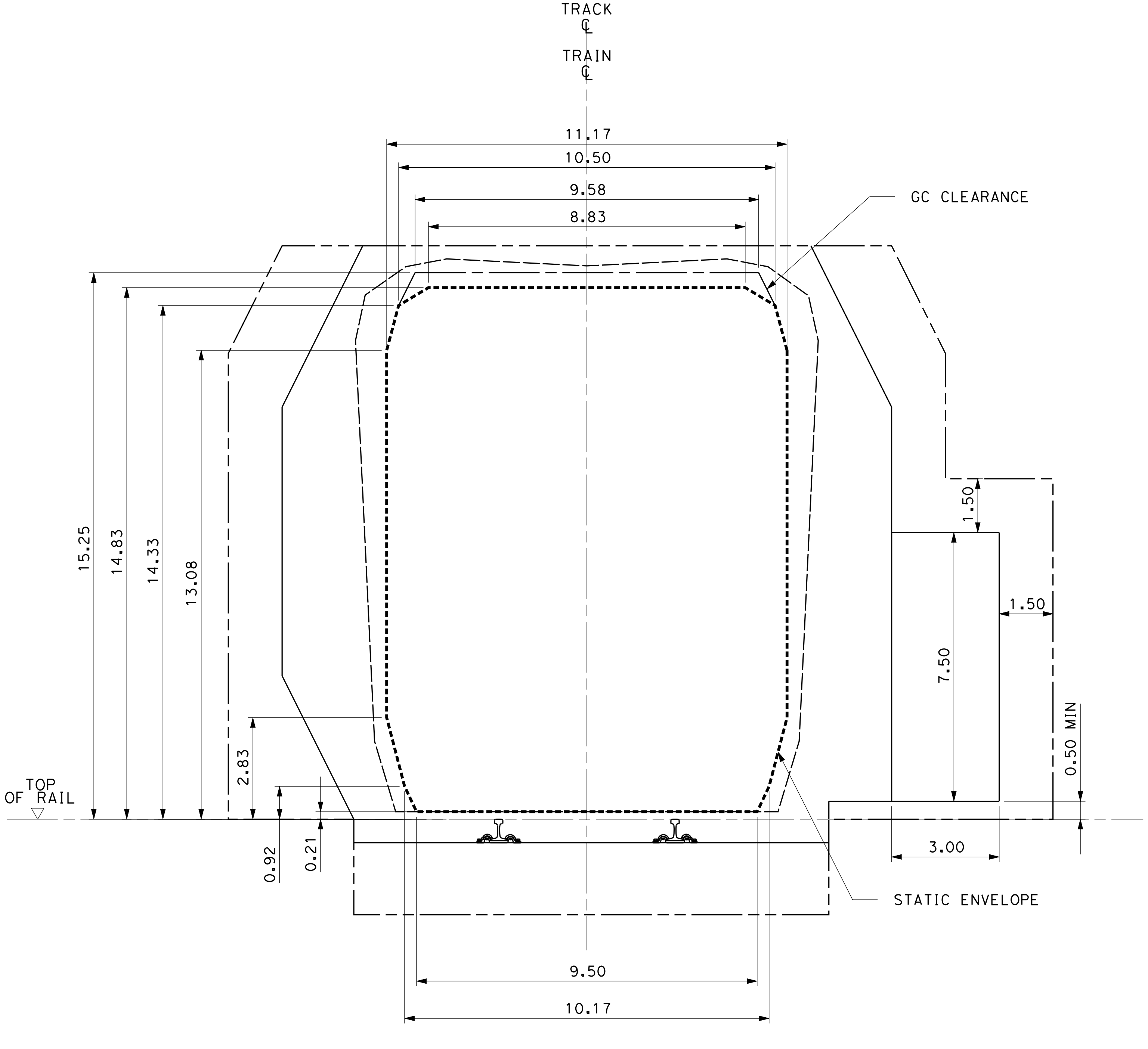
Figure X.2.4: DB (German) Standard Structure Gauge



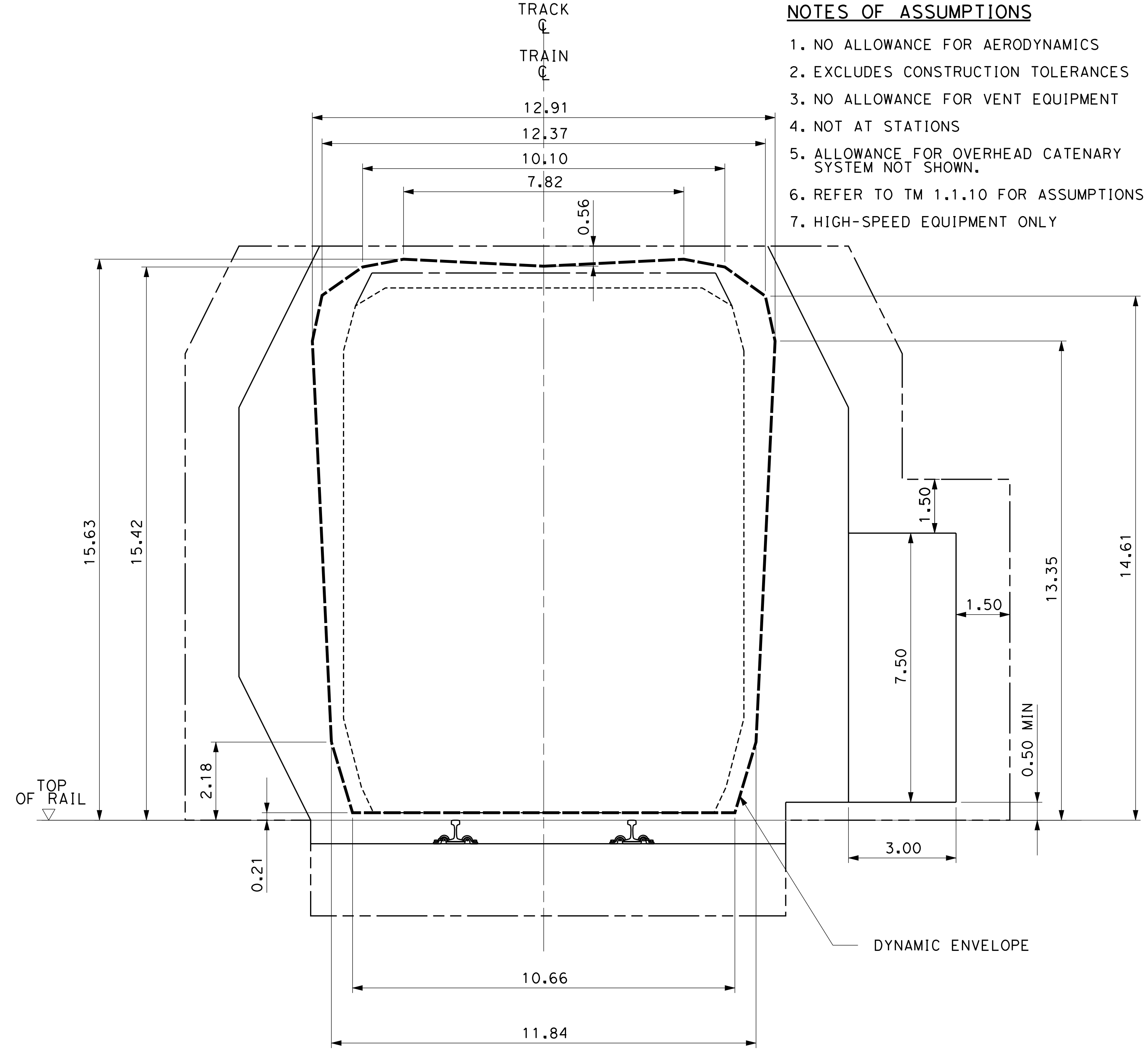
When this German Structure Gauge is compared to the TSI Kinematic Outline GC, it appears that there is a design relationship between these two outlines. The Kinematic Outline fits inside the Structure Gauge with a limited but reasonable allowance on both the sides and top. The German Structure Gauge also appears to be a good fit with the nominal contact wire heights given in the Energy Subsystem TSI.

Figure X.2.5: TSI Kinematic Envelope GC within German Structure Gauge





COMPOSITE STATIC ENVELOPE



COMPOSITE DYNAMIC ENVELOPE

NOTES OF ASSUMPTIONS

1. NO ALLOWANCE FOR AERODYNAMICS
2. EXCLUDES CONSTRUCTION TOLERANCES
3. NO ALLOWANCE FOR VENT EQUIPMENT
4. NOT AT STATIONS
5. ALLOWANCE FOR OVERHEAD CATENARY SYSTEM NOT SHOWN.
6. REFER TO TM 1.1.10 FOR ASSUMPTIONS
7. HIGH-SPEED EQUIPMENT ONLY

LEGEND

- COMPOSITE STATIC ENVELOPE, EXCEPT TSI GC AT TOP
- TOP OF TSI GC STATIC ENVELOPE
- COMPOSITE DYNAMIC ENVELOPE
- FIXED EQUIPMENT ENVELOPE
- STRUCTURE GAUGE

2 0 2 4
1/2"=1'-0"

REV	DATE	BY	CHK	APP	DESCRIPTION

DESIGNED BY G. HARRIS
DRAWN BY D. SOLTERO
CHECKED BY J. THOMPSON
IN CHARGE J. CHIRCO
DATE 04/16/10

PB PARSONS BRINCKERHOFF

CALIFORNIA HIGH-SPEED RAIL AUTHORITY
FLY CALIFORNIA
Without ever leaving the ground.

CALIFORNIA HIGH-SPEED TRAIN PROJECT

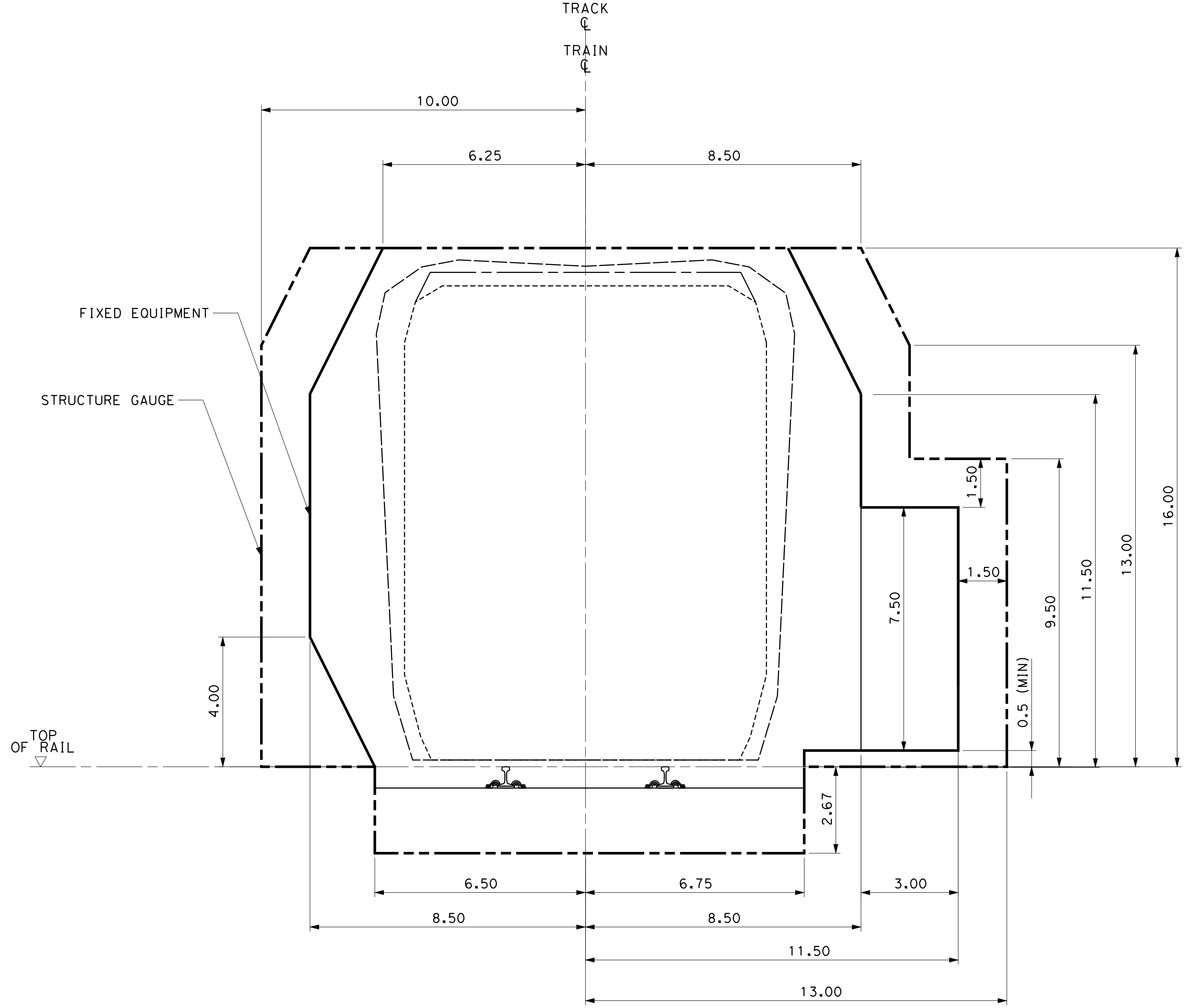
COMPOSITE VEHICLE
STATIC AND DYNAMIC ENVELOPE
TANGENT TRACK

CONTRACT NO. 13259
DRAWING NO. TM 1.1.10-A
SCALE 1/2"=1'-0"
SHEET NO. 1 OF 4

David

NOTES OF ASSUMPTIONS

1. NO ALLOWANCE FOR AERODYNAMICS
2. EXCLUDES CONSTRUCTION TOLERANCES
3. NO ALLOWANCE FOR VENT EQUIPMENT
4. NOT AT STATIONS OR TUNNELS
5. ALLOWANCE FOR OVERHEAD CATENARY SYSTEM NOT SHOWN.
6. REFER TO TM 1.1.10 FOR ASSUMPTIONS
7. HIGH-SPEED EQUIPMENT ONLY



FIXED EQUIPMENT ENVELOPE AND STRUCTURE GAUGE

LEGEND

- COMPOSITE STATIC ENVELOPE, EXCEPT TSI GC AT TOP
- TOP OF TSI GC STATIC ENVELOPE
- COMPOSITE DYNAMIC ENVELOPE
- FIXED EQUIPMENT ENVELOPE
- STRUCTURE GAUGE

2 0 2 4
1/2"=1'-0"

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REV	DATE	BY	CHK	APP	DESCRIPTION

DESIGNED BY G. HARRIS
DRAWN BY D. SOLTERO
CHECKED BY J. THOMPSON
IN CHARGE J. CHIRCO
DATE 04/16/10

PB PARSONS BRINCKERHOFF

CALIFORNIA HIGH-SPEED RAIL AUTHORITY
FLY CALIFORNIA
Without ever leaving the ground.

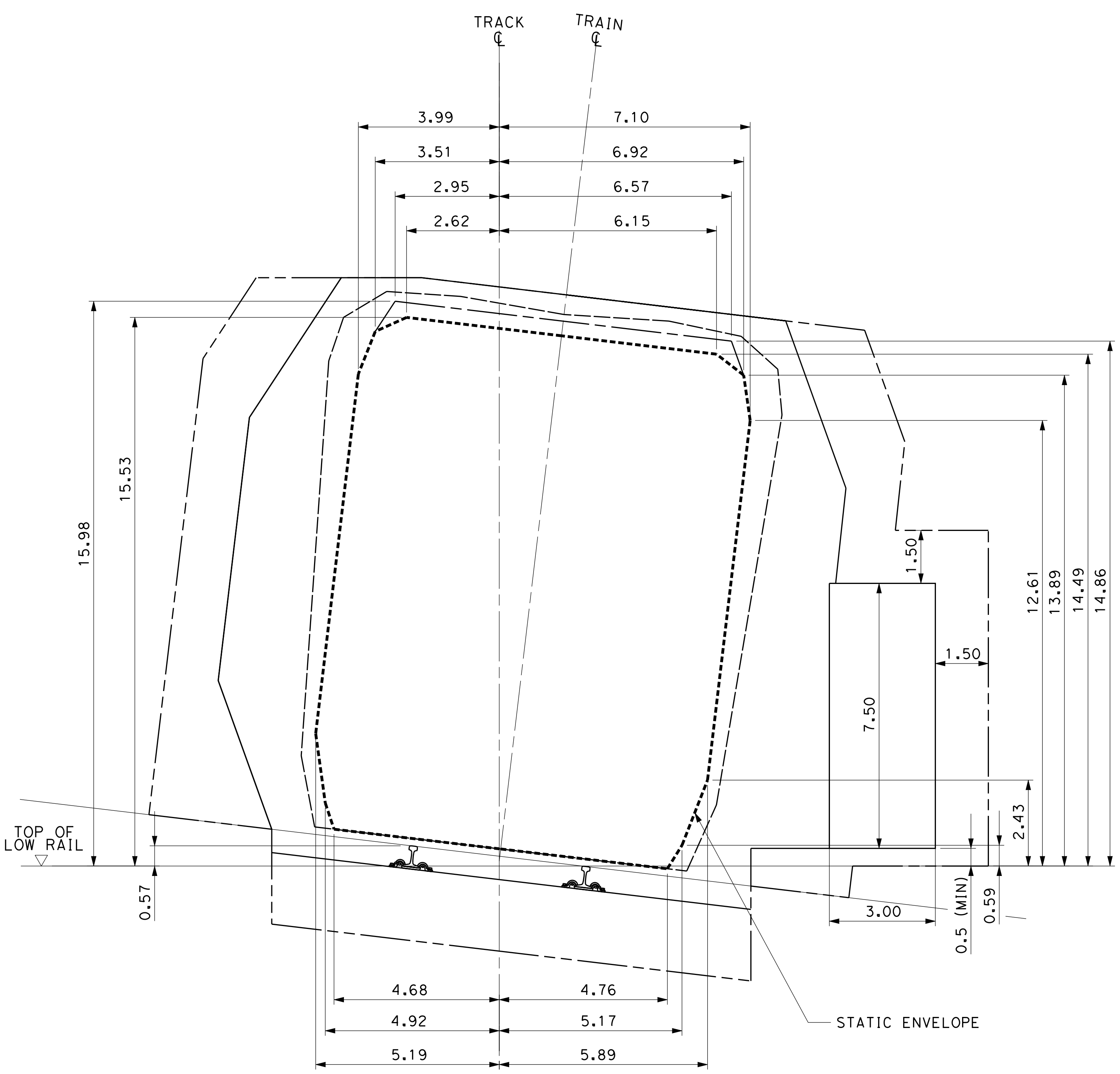
CALIFORNIA HIGH-SPEED TRAIN PROJECT

COMPOSITE VEHICLE
FIXED EQUIPMENT ENVELOPE AND STRUCTURE GAUGE
TANGENT TRACK

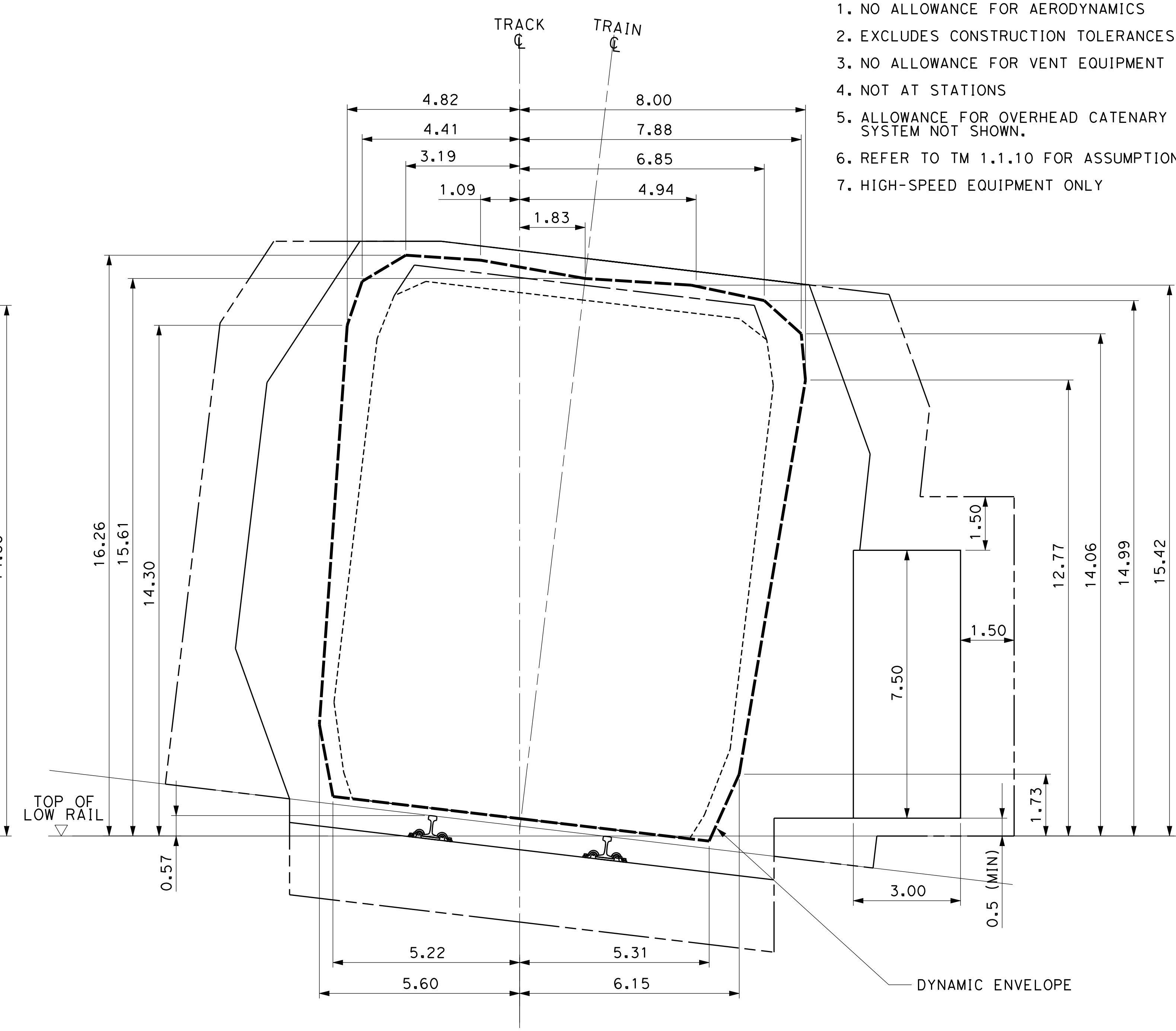
CONTRACT NO. 13259
DRAWING NO. TM 1.1.10-B
SCALE 1/2"=1'-0"
SHEET NO. 2 OF 4

NOTES OF ASSUMPTIONS

1. NO ALLOWANCE FOR AERODYNAMICS
2. EXCLUDES CONSTRUCTION TOLERANCES
3. NO ALLOWANCE FOR VENT EQUIPMENT
4. NOT AT STATIONS
5. ALLOWANCE FOR OVERHEAD CATENARY SYSTEM NOT SHOWN.
6. REFER TO TM 1.1.10 FOR ASSUMPTIONS
7. HIGH-SPEED EQUIPMENT ONLY



COMPOSITE STATIC ENVELOPE



COMPOSITE DYNAMIC ENVELOPE

LEGEND

- - - - - - COMPOSITE STATIC ENVELOPE, EXCEPT TSI GC AT TOP
—— — —— — TOP OF TSI GC STATIC ENVELOPE
— — — — — COMPOSITE DYNAMIC ENVELOPE
———————— FIXED EQUIPMENT ENVELOPE
—— — — —— STRUCTURE GAUGE

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1/2"=1'-0"

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David

REV	DATE	BY	CHK	APP	DESCRIPTION		
						DESIGNED BY G. HARRIS	PB PARSONS BRINCKERHOFF
						DRAWN BY D. SOLTERO	CALIFORNIA HIGH-SPEED RAIL AUTHORITY
						CHECKED BY J. THOMPSON	FLY CALIFORNIA Without ever leaving the ground.
						IN CHARGE J. CHIRCO	
						DATE 04/16/10	

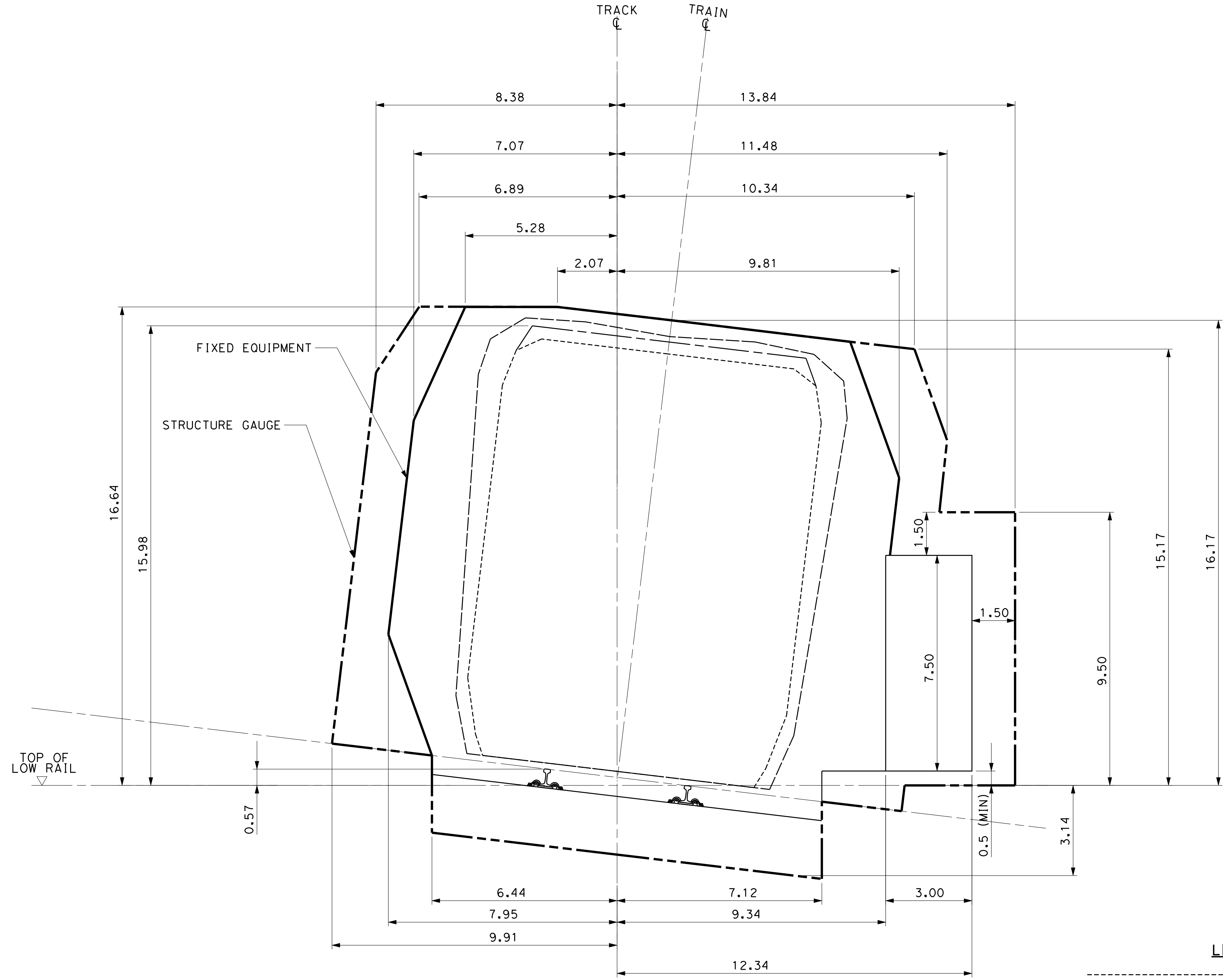
CALIFORNIA HIGH-SPEED TRAIN PROJECT

COMPOSITE VEHICLE
STATIC AND DYNAMIC ENVELOPE
SUPERELEVATED TRACK

CONTRACT NO.	13259
DRAWING NO.	TM 1.1.10-C
SCALE	1/2"=1'-0"
SHEET NO.	3 OF 4

NOTES OF ASSUMPTIONS

1. NO ALLOWANCE FOR AERODYNAMICS
2. EXCLUDES CONSTRUCTION TOLERANCES
3. NO ALLOWANCE FOR VENT EQUIPMENT
4. NOT AT STATIONS OR TUNNELS
5. ALLOWANCE FOR OVERHEAD CATENARY SYSTEM NOT SHOWN.
6. REFER TO TM 1.1.10 FOR ASSUMPTIONS
7. HIGH-SPEED EQUIPMENT ONLY



FIXED EQUIPMENT ENVELOPE AND STRUCTURE GAUGE

LEGEND

- COMPOSITE STATIC ENVELOPE, EXCEPT TSI GC AT TOP
- TOP OF TSI GC STATIC ENVELOPE
- COMPOSITE DYNAMIC ENVELOPE
- FIXED EQUIPMENT ENVELOPE
- STRUCTURE GAUGE

2 0 2 4
1/2"=1'-0"

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David

REV	DATE	BY	CHK	APP	DESCRIPTION

DESIGNED BY G. HARRIS
DRAWN BY D. SOLTERO
CHECKED BY J. THOMPSON
IN CHARGE J. CHIRCO
DATE 04/16/10

PB PARSONS BRINCKERHOFF

CALIFORNIA HIGH-SPEED RAIL AUTHORITY
FLY CALIFORNIA
Without ever leaving the ground.

CALIFORNIA HIGH-SPEED TRAIN PROJECT

COMPOSITE VEHICLE
FIXED EQUIPMENT ENVELOPE AND STRUCTURE GAUGE
SUPERELEVATED TRACK

CONTRACT NO. 13259
DRAWING NO. TM 1.1.10-D
SCALE 1/2"=1'-0"
SHEET NO. 4 OF 4